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1956.

THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

EIGHTH ANNUAL REPORT

OF THE

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

FOR

YEAR 1955-56.

Presented pursuant to Statute ; ordered to be printed, 1st *November*, 1956.

[*Cost of Paper* :—Preparation, not given ; 850 copies ; approximate cost of printing and publishing, £745.]

Printed and Published for the Government of the Commonwealth of Australia by
A. J. Arthur, Commonwealth Government Printer, Canberra.
(Printed in Australia.)

No. 89 [Group F].—F.6593/*56*.—Price 10s. 6d.

COMMONWEALTH MYCOLOGICAL INSTITUTE
27 MAY 1957

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COMMONWEALTH OF AUSTRALIA.

Commonwealth Scientific and Industrial Research Organization.

EIGHTH ANNUAL REPORT FOR YEAR 1955–56.

I. INTRODUCTORY.

1. General.

The Commonwealth Scientific and Industrial Research Organization was established on 19th May, 1949, when the Science and Industry Research Act 1949 was proclaimed. Under the Act the Organization took the place of the Council for Scientific and Industrial Research, which in turn had, in 1926, taken the place of the Institute of Science and Industry.

The powers and functions of the Organization are similar to those of the former Council and include the initiation and carrying out of research in connexion with, or for the promotion of, primary and secondary industries in the Commonwealth or any Territory of the Commonwealth; the training of research workers; the making of grants in aid of pure scientific apparatus and instruments, and the carrying out of scientific investigations connected with standardization, the collection and dissemination of information relating to scientific and technical matters; and acting as a means of liaison with other countries in matters of scientific research.

2. Executive.

Sir Ian Clunies Ross, C.M.G., D.V.Sc., LL.D., F.A.A., has been re-appointed as Chairman of the Executive for a further period of seven years.

Dr. F. W. G. White, C.B.E., M.Sc., Ph.D., has been re-appointed as Chief Executive Officer for a further period of seven years.

Mr. A. W. Coles has been appointed to the Executive of the Organization, to fill the vacancy caused by the retirement of Mr. A. B. Ritchie, who completed six years' service.

3. Advisory Council.

The following members retired from the Advisory Council on completion of their six-year period of appointment:—Professor J. P. Baxter, O.B.E., B.Sc., Ph.D., F.A.A.; Mr. D. T. Boyd, C.M.G.; Sir Macfarlane Burnet, M.D., Ph.D., F.A.A., F.R.S.; Sir Edward Lefroy; Sir John Madsen, B.E., D.Sc., F.A.A.; Professor D. M. Myers, B.Sc., D.Sc.Eng.; Mr. G. B. O'Malley, B.Met.E.; Sir David Rivett, K.C.M.G., M.A., D.Sc., F.A.A., F.R.S.; Professor Sir Samuel Wadham, M.A., Dip.Agr.

The following were appointed as Chairmen of State Committees:—

New South Wales—Professor H. R. Carne, D.V.Sc., Professor of Veterinary Pathology and Bacteriology, University of Sydney.

Queensland—Professor W. V. Macfarlane, B.Sc.Agr., M.A., M.D., Professor of Physiology, University of Queensland.

South Australia—Dr. A. R. Callaghan, C.M.G., B.Sc., D.Phil., Director of Agriculture, South Australia.

Tasmania—Mr. T. A. Frankcombe, Orchardist, Tasmania.

Victoria—Professor J. S. Turner, M.A., M.Sc., Ph.D., F.A.A., Professor of Botany, University of Melbourne.

Western Australia—Professor W. S. Bayliss, B.A., B.Sc., Ph.D., F.A.A., Professor of Chemistry, University of Western Australia.

The following new members have been co-opted to the Advisory Council:—

Mr. M. A. Mawby, D.Sc. (Hon.), F.S.T.C., F.A.A., Vice-Chairman of Consolidated Zinc Pty. Ltd. and a member of the Australian Aluminium Production Commission.

Mr. W. W. Pettingell, B.Sc., General Manager, the Australian Gas Light Company.

Mr. W. J. Russell, A.C.I.A., Western Australian grazier.

Mr. E. M. Schroder, Managing Director, Adelaide Cement Company Ltd.

Mr. H. B. Somerset, M.Sc., Managing Director, Associated Pulp and Paper Mills Ltd.

Professor A. D. Trendall, M.A., Litt.D., Master of University House, Australian National University.

Dr. J. Vernon, B.Sc., Ph.D., Senior Executive Officer, Colonial Sugar Refining Company Ltd.

Mr. A. B. Ritchie, M.A., Victorian grazier, formerly a member of the Executive.

4. Honours and Awards.

Sir Ian Clunies Ross, Chairman of the Organization: Honorary Degree of Doctor of Laws, University of Melbourne; member of the Council, Australian National University, Canberra: member of the Council, Melbourne University.

Professor Sir Samuel Wadham, School of Agriculture, University of Melbourne, retired member of the Advisory Council: Knight Batchelor.

Miss E. L. Archer, former Chief Librarian: Member of the Order of the British Empire.

Mr. I. M. McLennan, General Manager of Broken Hill Co. Pty. Ltd. and member of the Advisory Council: Order of the British Empire.

Sir Edward Lefroy, a member of the Advisory Council: Knight Batchelor.

Mr. W. A. Gunn, member of the Advisory Council: Companion of the Order of St. Michael and St. George.

Dr. E. A. Cornish, Chief of the Division of Mathematical Statistics: President of the Biometric Society.

Dr. M. J. D. White, Senior Research Fellow, Division of Plant Industry: Fellow of the Australian Academy of Science.

Dr. M. F. Day of the Division of Entomology was elected to the Australian Academy of Science.

Dr. A. L. Mathieson, Principal Research Officer, Division of Industrial Chemistry: degree of Doctor of Science, University of Melbourne.

Dr. M. E. Winfield, Senior Research Officer, Division of Industrial Chemistry: degree of Doctor of Science, University of Western Australia.

Dr. D. F. Martyn, Chief Scientific Officer, Radio Research Board: President of the Ionosphere Commission, International Union of Radio Science.

Dr. D. Martin, Officer-in-charge, Tasmanian Regional Laboratory: degree of Doctor of Science, University of Tasmania.

Dr. L. B. Bull, former Chief of the Division of Animal Health and Production: A.N.Z.A.A.S. Mueller Memorial Medal.

Mr. A. J. Anderson, Senior Principal Research Officer, Division of Plant Industry: 1956 Australian Medal for Agricultural Science, Australian Institute of Agricultural Science.

Dr. D. F. Stewart, Officer-in-charge, McMaster Animal Health Laboratory: elected President of the Australian Veterinary Association for 1955-56.

Dr. H. W. Worner, Principal Research Officer, Physical Metallurgy Section, Chair of Metallurgy, University of Melbourne.

Dr. M. Chaikin, Research Officer, Wool Textile Research Laboratory, Sydney: Chair of Textile Technology, New South Wales University of Technology.

5. RETIREMENTS.

Professor J. N. Greenwood, D.Sc., M.Met.E., has retired from his honorary position as Officer-in-charge of the Physical Metallurgy Section. Professor Greenwood had had a long association with the Organization and its predecessor, the C.S.I.R., his first work in collaboration with C.S.I.R. dating back as far as 1926.

Mr. E. S. West, B.Sc., M.S., has retired as Officer-in-charge of the Irrigation Research Station, Griffith. Mr. West had been on the research staff of the Irrigation Research Station since its inception in 1924 and has made a major constribution to the solution of the problems of the Murrumbidgee Irrigation Areas.

6. NEW CHIEF.

Dr. G. F. Humphrey, M.Sc., Ph.D., has been appointed Chief of the Division of Fisheries and Oceanography in succession to Dr. H. Thompson, who retired in 1954. Dr. Humphrey was formerly Senior Lecturer in Biochemistry at the University of Sydney. At the time of his appointment the name of the Division was changed from Fisheries to Fisheries and Oceanography to reflect more accurately its scientific activities.

7. NEW OFFICER-IN-CHARGE.

Professor H. W. Worner, D.Sc., M.Sc., has been appointed Officer-in-charge of the Physical Metallurgy Section. Professor Worner has been a member of the staff of the Organization and its predecessor since 1940, first in the Lubricants and Bearings Section, later in the Division of Industrial Chemistry, and finally as leader of a research group working on titanium in the Physical Metallurgy Section.

8. OVERSEAS VISITORS.

Much stimulation and help to Australian research was given by a number of leading scientists from overseas who visited Australia during the year, many of whom co-operated with our own research workers on various projects.

The Organization was fortunate to have the following scientists from American research establishments working in the various Divisions and Sections under Fulbright awards:—

Dr. Harlan K. Pratt, Associate Professor and Assistant Plant Physiologist, University of California, in the Division of Food Preservation and Transport; Dr. Alfred J. Stamm, of the United States Forest Products Laboratory, Madison, Wisconsin, in the Division of Forest Products; Professor L. Yardley Beers, of New York University, in the Division of Electrotechnology; Professor Lorin E. Harris, Professor of Animal Husbandry, Utah, in the Division of Biochemistry and General Nutrition, Adelaide; Dr. R. T. Clark, Co-ordinator, Beef Cattle Breeding Research, United States Department of Agriculture, Denver, Colorado, in the McMaster Animal Health Laboratory, Sydney.

It is pleasing to note that three senior scientists have been working in the Organization's laboratories under the Royal Society and Nuffield Foundation Commonwealth Bursaries Scheme:

Professor P. A. Sheppard, head of the Department of Meteorology at Imperial College, London, spent four months with the Division of Meteorological Physics. Professor Sheppard also spent some time in the Division of Radiophysics to discuss problems in cloud and rain physics.

Mr. M. V. Tracey, Senior Biochemist, Rothamsted Experimental Station, United Kingdom, with the Wool Textile Research Laboratory, Parkville, in the field of biological degradation of cellulose and chitin.

Professor L. King, a geomorphologist of the University of Natal, Durban, South Africa, with the Division of Soils to study land formations in the southern States of the Commonwealth.

The following senior overseas scientists also visited the Organization:—

Professor F. Went, Director of Earhart Plant Research Laboratory, California Institute of Technology, Pasadena, U.S.A.; Professor M. G. Kendall, Director, Division of Research Techniques, and Professor of Statistics, London School of Economics; Dr. C. D. Converse, Officer-in-charge, Sabi Valley Experiment Station, Southern Rhodesia; Dr. Mansel Davies, University College, Aberystwyth, Wales; Mr. J. B. Brooke, Director of the Industrial Development Laboratories of the D.S.I.R., New Zealand; Mr. J. Christodoulu, an Agricultural Superintendent of the Department of Agriculture, Cyprus; Dr. R. Mirams, a wood technologist of New Zealand Forest Products Limited; Mr. A. J. Semple, Range Management Specialist of the Animal Production Branch of the United Nations Food and Agriculture Organization; Mrs. Sunanda Narayan, of the Wool Laboratory, Rajastan, India.

In addition two groups of distinguished scientists from overseas visited the Organization during the year as delegates to the Wool Textile Research Conference and the Conference of Directors of Building Research (*see* Sections 14 and 15 of this Chapter).

9. FACILITIES FOR RESEARCH.

With current costs so high there is the danger that the Organization's laboratories may fall behind in facilities for research, particularly in the costly equipment which is essential if research staff are to remain leaders in their respective fields and make the greatest possible contribution to Australian science and technology. Although the expenditure on salaries has reflected the decreasing purchasing value of the Australian pound, the expenditure on equipment has failed to do so. This condition is illustrated by a comparison of the ratios of expenditure on salaries and equipment over the last ten years. Whereas in the Division of Industrial Chemistry during 1945-46, 3.4 times as much was spent on salaries as on equipment, by 1950-51, the ratio has increased to 6.5 and has remained at about this level since that time. It should be noted that equipment deficiencies which arise in this way are cumulative in their effect on the standard of facilities provided in a laboratory. This trend is, unfortunately, not confined to this Organization; throughout Australia, scientific research in the universities is being hampered by inadequate equipment, one direct result of which has been the loss of many prominent chemists to overseas laboratories. The experience of the universities proves that it will become increasingly difficult to retain top-rank research workers in the Organization, unless financial provision can be made to bring equipment up to date.

10. GIANT RADIO TELESCOPE.

Following last year's gift from the Carnegie Corporation, the Rockefeller Foundation of America has now made a gift of 250,000 dollars towards the cost of building the giant radio telescope planned by the Division of Radiophysics in Sydney.

With these two magnificent contributions from America, generous support received from private donors in Australia and the Commonwealth Government's offer to match all such donations, the Radio Astronomy Trust now has in sight more than £520,000 towards the project.

Although further contributions will still be necessary to complete the construction of this immense scientific instrument, a contract has been let for a design study to be undertaken by Messrs. Freeman, Fox, and Partners, a leading firm of consulting engineers in the United Kingdom. A survey is being made for a site near Sydney suitable for the contruction of the radio telescope.

11. PATENTS COMMITTEE.

In 1954 a Patents Policy Committee was appointed by the Executive to examine the Organization's patent policy. As the result of the report of this Committee the Executive has revised the Organization's policy with respect to patents, and has established a permanent Patents Committee which is empowered to examine new proposals for patents, to review current patents periodically, and to decide on the best methods of exploiting the Organization's patents for the benefit of the Commonwealth of Australia. Letters Patent granted to the Organization both in Australia and overseas during the current year have been included in Chapter XXXV.

12. TRACER ELEMENTS INVESTIGATIONS.

It has been decided to discontinue the Tracer Elements Investigations as a separate entity at the Chemistry School of the University of Melbourne, and the Unit has now been disbanded. The Organization is very indebted to the University of Melbourne and particularly to the Department of Chemistry for their assistance in providing accommodation for this research team.

13. CO-OPERATIVE RESEARCH WITH INDUSTRY.

The newly-formed Industrial Research Liaison Section, established to strengthen liaison between the Organization and secondary industries, has now completed its first year of operation. The report of the Section's work is in Chapter XXXII., Section 4.

Support for the Australian Leather Research Association and the Bread Research Institute of Australia has continued under financial arrangements whereby the Organization makes a contribution to their running costs.

The Wine Research Institute has now issued its second annual report. At the conclusion of the year the Institute took over the functions of the former Oenological Research Committee.

Plans have now been completed for support for research into problems of the tobacco-growing industry in Australia, in which the Division of Plant Industry has been participating for some years. As part of the plan the Organization, with the support of the tobacco industry, proposes to establish a Tobacco Research Institute in north Queensland, where the main development of tobacco-growing in Australia is expected to take place. The Institute will be established initially within the administrative framework of the Division of Plant Industry. Funds for the programme are being made available by the manufacturers, the growers, and the Commonwealth Government. The position of Director has been advertised and applicants will shortly be interviewed.

During the current year negotiations have been effected for a number of new sponsored research projects to be undertaken on a co-operative basis with industry and other establishments. These projects include—

Investigations at the Division of Building Research sponsored by the Technical Committee of the Paint and Varnish Section of the Victorian Chamber of Commerce of problems associated with the painting of plaster surfaces; support by C.S.R. Chemicals Pty. Ltd. for the Division of Physics in its work on the problem of colour analysis; support by the Australian Dairy Produce Board for the Dairy Research Section to assist in the maintenance of a new cheese and casein starter service and the construction of cheese maturing rooms; a co-operative project in the Ore-dressing Laboratory, Melbourne, with Territory Enterprises Pty. Ltd., for the development of a flotation process suitable for the treatment of mixed base metal ore adjacent to White's uranium ore body at Rum Jungle; investigation in the Ore-dressing Laboratory, Melbourne, on the flotation of a base metal ore deposit in the Northern Territory for Consolidated Zinc Pty. Ltd.; support by the Australian Plywood Board for plywood investigations at the Division of Forest Products; research at the Division of Industrial Chemistry on the extraction of copper from pyritic concentrates on behalf of Mt. Morgan Ltd., Mt. Lyell Mining and Railway Co. Ltd., Mt. Isa Mines Ltd., and Peko Mines N.L.; a project at the Division of Industrial Chemistry for Rio Tinto Co. Ltd. on the recovery of uranium from unfiltered pulp.

The above co-operative research projects are additional to those noted in previous Annual Reports. A full list of contributions and donations for research received by the Organization is given in Chapter XXXVI., Section 2.

14. INTERNATIONAL WOOL TEXTILE RESEARCH CONFERENCE.

The International Wool Textile Research Conference, organized by the Organization with the co-operation of the Australian Wool Bureau and the Commonwealth Wool Adviser, was held in August, 1955. The generous financial support of the Australian Wool Bureau, without which the conference could not have been held, is warmly acknowledged. Fifty-one scientists from ten countries overseas attended, in addition to 59 Australian scientific workers. Sessions of the Conference were held successively at the Wool Textile Research Laboratories in Sydney, Geelong, and Melbourne.

Among the notable overseas scientists who attended, all of whom are active in some branch of research on wool or other protein material, were Professor W. T. Astbury, F.R.S., and Professor J. B. Speakman, of Leeds University; Dr. A. B. C. Cassie, Director of the British Wool Industries Research Association; Professor J. H. Dillon, of the Textile Research Institute, Princeton, N. J.; Dr. A. J. P. Martin and Dr. R. L. M. Synge, joint Nobel prize winners for their contribution to knowledge of proteins; Dr. F. Sanger, F.R.S., of Cambridge University; Professor R. B. Corey, of the California Institute of Technology; Professor Henry Eyring and Professor Emil Smith of the University of Utah; Professor H. Zahn, of Heidelberg University; and Dr. K. J. Lindberg, of the Swedish Textile Research Institute, Gothenburg.

This conference was the first international meeting of scientists engaged in research on wool textile and related fields of science, and it is fitting that Australia should have taken the initiative in organizing a conference on a subject which holds such vital importance for her economy. Some of the leading overseas delegates were so impressed with the opportunities provided by the Conference for stimulating scientific research on wool and for spreading knowledge of improvements in wool processing among representatives of the leading wool textile manufacturing countries that they have strongly advocated the holding of other meetings of this type in the future. Only by co-ordinating research in this way can the wool interests hope to match the immense scientific effort being devoted to the improvement of some of the other textile fibres. The papers presented to the conference are to be published in five volumes of Proceedings.

15. Meeting of Commonwealth Directors of Building Research.

In April the directors of the building research laboratories of the British Commonwealth and the United States of America met in Australia to discuss matters concerned with building research.

Those who attended the conference were Dr. F. M. Lea, Director, Building Research Station. D.S.I.R., Great Britain; Mr. R. F. Legget, Director, Division of Building Research, National Research Council, Canada; Lt.-General H. Williams, Director, Central Building Research Institute, C.S.I.R., India; Mr. N. Stutterheim, Director, National Building Research Institute, C.S.I.R., South Africa; Mr. W. F. Roeser, Consultant to Building Technology Division, National Bureau of Standards, U.S.A.; Mr. H. A. G. Sani, Executive Engineer, Government of West Pakistan (observer); Mr. D. V. Isaacs, Director, Commonwealth Experimental Building Station, Sydney; and Mr. Ian Langlands, Chief, Division of Building Research, C.S.I.R.O., Melbourne.

At the meetings which were held at the Commonwealth Experimental Building Station, Sydney, and at the Division of Building Research, Melbourne, there was informal discussion of current research programmes and an exchange of ideas on matters of mutual interest in the field of building research.

16. Collaboration with the Universities.

The work of the Organization performed by units within the Universities is described in the appropriate sections of this report. However, during the year a number of new arrangements were made with the Universities.

The Organization's Ore-dressing Laboratory in Melbourne moved into the new building of the Department of Mining, University of Melbourne. The erection of this building was partly financed by the Organization.

The high-speed electronic computor, C.S.I.R.A.C., constructed in the Division of Radiophysics, has been transferred on loan to the Department of Applied Mathematics of the University of Melbourne where the instrument is now in use.

Arrangements have been finalized with the University of Queensland for the establishment of two Research Fellowships in Parisitology.

A section of the Organization's work on absorption spectroscopy is to be undertaken at the Chemistry Department of the University of Western Australia. In addition the marsupial research work of this University's Zoology Department is to be supported.

The University of Sydney has collaborated with the Organization in investigations of fruit fly, nitrogen metabolism, and subterranean clover in the New England District. Assistance has also been given by the University of Adelaide with the work on the biological effects on sheep of phenothiazine, and by the University of Melbourne in plant biochemistry investigations.

The Organization wishes to acknowledge the assistance it has received from the Universities in these co-operative research projects, which are such a necessary part of its work.

17. Science and Industry Endowment Fund.

During the year the Executive, as Trustees of the Science and Industry Endowment Fund, awarded grants to assist research workers as follows:—

Mr. Tarlton Rayment, for entomological work on bees and wasps; Mr. A. W. Parrott, for taxonomic work on Australian parasitic wasps; Mr. N. V. Dobrotworsky, for work on the systematics and ecology of the Australian mosquito; Mr. D. G. Morgan, for a study into techniques of bird population sampling; Dr. D. J. Pearson, for work on the comparative anatomy and embryology of marsupials. In addition, Miss Coryl Skewes was given assistance towards systematic botanical research work being undertaken at the Royal Botanic Gardens, Kew.

Two travel grants were made during the year. These were to Dr. W. A. Wood to enable him to attend the Conference on the Failure of Metals by Fatigue in America, and to Mr. E. E. Bond, who attended the International Symposium on Cereal Grains, held in New York.

During the year a studentship was awarded to Mr. N. W. Moore to enable him to study the physiology of reproduction under Dr. Mann at the University of Cambridge.

18. Overseas Visits, Fellowships, and Studentships.

Officers of the Organization represented Australia at a number of important overseas scientific conferences during the year. These included the Third International Meeting on the Reactivity of Solids, Madrid; the Symposium of the International Union of Crystallography, Madrid; the International Commission of Optics, Massachusetts; the International Whaling Commission Conference, London; the World Symposium on Applied Solar Energy, Arizona; Meeting of the International Astronomical Union, Dublin; the United Nations Conference on the Peaceful Uses of Atomic Energy, Geneva; the Fourth National Clay-minerals Conference, Pennsylvania; and the Sixth Meeting of the Indo-Pacific Fisheries Council.

Ten officers went overseas for short periods as advisers on F.A.O. assignments, at the invitation of U.N.E.S.C.O., under the Colombo Plan, or at the invitation of overseas governments.

During the year a number of officers were sent overseas for periods from two to twelve months to collect information on new developments in scientific research and to acquire general experience in their particular fields. In addition four officers went overseas at the invitation of overseas universities and other research organizations for consultations concerning special aspects of their work.

Nine Australian students were given awards to enable them to undertake research training at overseas universities. One overseas studentship was awarded from the Science and Industry Endowment Fund, and four Divisional studentships were awarded to officers of the Organization to enable them to undertake training overseas.

Twenty-four post-graduate studentships were awarded at Australian Universities and one studentship was awarded to a post-graduate student from the United Kingdom to enable him to undertake work in Australia.

The Organization continued to provide training facilities for students and fellows coming to Australia under the auspices of the Colombo Plan, F.A.O., and U.N.E.S.C.O.

19. Buildings and Accommodation.

During the year the following buildings were completed:—

New South Wales—
  - Camden—Completion of "Harben Vale" for Radio Research Laboratories.
  - "Chiswick"—New bachelors' quarters at field station.

Cronulla—Small radiochemistry annexe for Division of Fisheries and Oceanography.
Gosford—Extension of laboratory and new fruit fly annexe.
Prospect—Climate control building.
Ryde—Main laboratory for Wool Textile Research.
Sydney—Extension of Zoology School at University for animal genetics.
  Subdivision of dead room, National Standards Laboratory.
  Plating shop for National Standards Laboratory.

South Australia—
Glenthorne—Experimental fodder preparation building.

Western Australia—
Kelmscott—Glass-house.
Kojonup—Residence for Officer-in-charge, " Glen Lossie ".

Victoria—
Fishermen's Bend—Industrial Chemistry Workshop.
Highett—Store for Head Office.
  Store for Division of Forest Products.

The following projects are in course of construction:—

Australian Capital Territory—
Canberra—Air-conditioned insectary for Division of Entomology.

New South Wales—
Prospect—Animal House No. 1.

Tasmania—
Hobart—Food Preservation annexe at " Stowell ".

Victoria—
Aspendale—Main building and wind tunnel carpentry shop for Meteorological Physics.
Highett—Workshop for Engineering Section.
Parkville—Physical chemistry laboratory for Wool Textile Research Laboratory.

20. FINANCE.

Chapter XXXVI. gives details of the expenditure of £6,266,234 incurred during 1955-56 by the Organization from all funds at its disposal. The major portion of this sum was derived from the Commonwealth Treasury—£4,716,313 was expended in connexion with normal research activities, £100,431 on grants to bodies such as the Commonwealth Agricultural Bureaux, and 10,738 on capital works under the control of the Organization. The remainder was expended on investigations financed from contributions, viz. £873,451 from the Wool Research Trust Account, £317,885 from the Wool Industry Fund, £74,534 from miscellaneous receipts, and £172,882 from grants including special revenue. Certain other expenditure was incurred by the Commonwealth Department of Works on building projects for the Organization from funds controlled by that Department. Transactions for rentals and acquisition of sites and buildings were arranged from funds made available to the Department of the Interior for expenditure on behalf of the Organization.

The Organization is particularly gratified by the way in which various bodies continue to support it, and by the marked interest evinced by certain sections of industry which have provided donations for co-operative research. Among the many contributions received, reference may be made to those of the Commonwealth Bank of Australia (through the Rural Credits Development Fund), Australian Meat Board, Australian Dairy Produce Board, Australian Wine Research Institute, Australian Egg Board, the Queensland Meat Industry Board, the New South Wales Department of Agriculture, the New South Wales Water Conservation and Irrigation Commission, the Metropolitan Meat Industry Board of New South Wales, Burdekin Bequest, the Alexander Fraser Memorial Fund, the Commonwealth Dried Fruits Control Board, the dried fruits industry, Australasian Institute of Mining and Metallurgy, State Electricity Commission of Victoria, Australian Cement Manufacturers' Association, the wool textile industry, the timber industry, and the pulp and paper industry.

21. ORGANIZATION.

For the purpose of carrying out its research work the Organization has established a number of Divisions and Sections. The Divisions, of which there are now 17, comprise the major establishments, which may be further subdivided into Sections; there are also 19 independent Sections comprising establishments which have not reached a stage of development, so far as the scope and magnitude of their operations are concerned, to justify their designation as Divisions.

In the present Report an attempt has been made to group the material according to its subject matter rather than according to the Divisions or Sections concerned. Additional chapters and appropriate cross-references have been inserted, however, to permit the work of any particular Division to be reviewed as a whole.

As the Organization's investigations extend on a Commonwealth-wide basis and as many of the investigations which are being conducted—particularly those concerned with problems affecting the agricultural and pastoral industries—necessitate experimental work in the field, a number of branch laboratories and field stations have been established in various parts of Australia.

The Head Office of the Organization is in Melbourne and associated with it are the Organization's Central Library, Agricultural Research Liaison Section, Industrial Research Liaison Section, Films Unit, and Editorial, Publications, and Translation groups. The Organization also maintains Australian Scientific Liaison Offices in London and Washington.

The Divisions which have been established (in order of their formation) are as follows:—

Plant Industry, with head-quarters at Canberra and main laboratories at Canberra and Brisbane, regional laboratories at Perth, Hobart, and Deniliquin, New South Wales, and field stations and experiment farms at Canberra, Australian Capital Territory, Lawes and Applethorpe, Queensland, Trangie, New South Wales, and Kojonup, Western Australia.

Entomology, with head-quarters and main laboratories at Canberra, a smaller laboratory in Sydney, and field stations at Trangie, New South Wales, Rockhampton, Queensland, and Perth.

Animal Health and Production, with head-quarters in Melbourne and main laboratories in Melbourne, Sydney, Prospect, New South Wales, and Brisbane; and field stations at Armidale and Badgery's Creek, New South Wales; Cunnamulla, Amberley, " Belmont ", and Rockhampton, Queensland; and Werribee and Tooradin, Victoria.

Biochemistry and General Nutrition, with head-quarters at Adelaide and field stations at O'Halloran Hill, Robe, and Brecon, South Australia.

Soils, with head-quarters and laboratories at Adelaide, and branch laboratories at Perth, Canberra, Brisbane, Melbourne, and Hobart.

Forest Products, Melbourne.

Food Preservation and Transport, with head-quarters and main laboratories at Sydney, branch laboratories in Brisbane and Hobart, and minor laboratories at Gosford, New South Wales.

Fisheries and Oceanography, with head-quarters and main laboratories at Cronulla, New South Wales, laboratories in Perth and Melbourne, and field stations at Hobart and Thursday Island.

Metrology, Physics, and *Electrotechnology*, comprising together the National Standards Laboratory, Sydney.

Radiophysics, Sydney.

Industrial Chemistry, with head-quarters and main laboratories in Melbourne and branch laboratories in Sydney, Adelaide, and Perth.

Tribophysics, Melbourne.

Building Research, Melbourne.

Mathematical Statistics, Adelaide.

Meteorological Physics, Melbourne.

The following are the Sections:—

Irrigation Research Stations, at Merbein, Victoria (Murray Irrigation Areas), and Griffith, New South Wales (Murrumbidgee Irrigation Areas).

Radio Research Laboratories, with head-quarters at Camden, New South Wales, and laboratory in Sydney.

Plant Fibre, Melbourne.

Ore-dressing Investigations, Melbourne and Kalgoorlie, Western Australia.

Minergraphic Investigations, Melbourne.

Dairy Research, Melbourne.

Coal Research, Sydney.

Physical Metallurgy, Melbourne.

Wildlife Survey, with head-quarters in Canberra and field stations at Perth, Albury, New South Wales, and Woodstock, Port Hedland, Western Australia.

Mathematical Instruments, Sydney.

Wool Textile Research Laboratories, with head-quarters in Melbourne and additional units in Sydney and Geelong, Victoria.

Land Research and Regional Survey, with head-quarters in Canberra and field stations at Alice Springs, Northern Territory, Katherine, Northern Territory, and in the Kimberley region, Western Australia.

Agricultural Research Liaison, Melbourne.

Animal Genetics, Sydney.

Engineering, Melbourne.

Industrial Research Liaison, Melbourne.

In addition, Regional Centres (co-operative research units staffed with officers from the appropriate specialist Divisions to attack the problems of a particular region) have been established as follows:—

Tasmanian Regional Laboratory, Hobart.

Western Australian Regional Laboratory, Perth.

II. SOILS.

1. GENERAL.

Scientific appreciation of Australian soils is basic to any proper land use. The efficient development and use of land resources to meet expanding national and world requirements—improvements in farming methods, more intense cultivation, the understanding of fertility problems of immense significance in Australia, and soil conservation, all require a fundamental knowledge of the soil.

The Organization's research in this field is undertaken by the Division of Soils with head-quarters at the Waite Agricultural Research Institute, University of Adelaide. Work on soils with special reference to their behaviour under irrigation is undertaken at the Commonwealth Research Station (Murray Irrigation Area), Merbein, Victoria, at the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales (*see* Chapter IV., Sections 2 and 3), and at the Regional Pastoral Laboratory, Deniliquin, New South Wales (*see* Chapter 3).

Division of Soils.—The Division is having difficulty in obtaining research staff particularly for work in pedology and chemistry.

During the year through an arrangement with the University of Adelaide the Division's Clay Mineralogy Section was accommodated in new laboratories in the Geology Department.

Assistance has been given in University teaching in soil science where officers have given short courses of lectures in the Agricultural degree course and in soil mechanics in a Civil Engineering course. These with the research programme have promoted good understanding and given grounds for co-operation. Relations with F.A.O. and the Colombo Plan programme have been maintained, and with the latter instruction and working programmes given to students and Asian visitors.

2. SOIL SURVEY AND PEDOLOGY.

(Division of Soils.)

(a) *Western Australia.*—On the coastal plain the field work for the detailed soil survey of the Pinjarra-Waroona area of 140,000 acres was completed during the year, and a report and soil map are being prepared. A Soils and Land Use Report on an area of 20,000 acres at Harvey is now ready for submission. The data from the surveys, together with that from reconnaissance traverses at other selected points, form the basis for the pedological study of the coastal plain south of Perth. The characteristics of the soils, both field and laboratory, and their distribution, related to modern geomorphological concepts, indicate a definite relative age sequence. From the foot of the Darling Scarp an alluvial plain slopes gently westwards, and it is on this that the oldest soils, probably of late Pliocene age, are found. Superimposed on this surface are more recent alluvial deposits associated with past or present stream courses. Further to the west the older alluvial plain is overlain by the coastal sand dunes, the younger of which, nearer the sea, are highly calcareous, becoming progressively less calcareous with progress inland to the older dunes.

Work on the soils of the wheat belt has been continued in the York area. Detailed survey near Kauring last year indicated the nature of the mid Tertiary surface still preserved there, and the relationship between soils and topography on it. Further detailed work has now been commenced in the Avon Valley and the higher ground to the east, where the mid Tertiary surface has been extensively truncated and dissected. In addition, a preliminary reconnaissance has been made in the Merredin area, where a pedological study of the soils of the drier part of the wheat belt is due to begin.

In the Great Southern District revision and correlation of work previously carried out in the Mount Barker-Cranbrook area have been continued and a new soil association map covering 900 square miles has been compiled.

(b) *South Australia.*—All the field work and in large part the land use reports for the Barossa District survey have been completed and await publication in four parts. The reports, following that of the Nuriootpa area previously published, together represent a very full study of the soils of the district which is the most important single wine-producing area in Australia. They cover the following units:—(i) the Nuriootpa area (*see* C.S.I.R.O. Soils and Land Use Series No. 13 (1954)); (ii) the Angaston-Springton and Tanunda Creek-Trial Hill areas; (iii) the Greenock-Gomersal area; (iv) the Tanunda-Williamstown area. The soil map for the whole Barossa District showing the distribution of the major soil groups has been compiled and virtually completes the work except for a later pedological discussion. Data for a memorandum on soil and climatic factors in relation to wine type and quality were obtained from the Barossa studies, and have proved of value to those responsible for the future research of the Wine Research Institute.

The survey of the area around Lakes Alexandria and Albert, South Australia, progressed favourably during the year. This region has available large supplies of fresh water which might be used for some irrigation. Studies have been made of soil salinity and irrigability, and the classification and correlation of the soil groups have been carried out. The survey will provide much needed basic data concerning the soils and their potential under rainfall conditions as well as the desirability of their more intensive development under irrigation.

The investigations at Yudnapinna Station in the north-western pastoral country, commenced in 1954, were concluded this year. A reconnaissance soil survey of the entire property of about 1,300 square miles and five separate detailed surveys totalling about 10,000 acres were made. A number of infiltration trials were conducted on typical soils. Rain gauges were installed on several dam catchments and water intakes were measured at these dams after rains in order to obtain run-off data. The report of the Yudnapinna investigations now completed includes an analysis of the available climatic data, a brief description of the physiography and geology, an account of the vegetation, descriptions of and a map showing distribution of soil types and soil associations, and a presentation and discussion of the data relating to soil water, infiltration, and run-off.

During May and June some reconnaissance examinations of the soils in the far north-west of South Australia were made in order to compare the soils and landscapes with those previously studied at Yudnapinna. It is hoped that these comparisons will assist in the solving of certain pedological problems which were manifest there and will lead to a better understanding of this arid portion of Australia generally. Following a request from the Department of Interior a number of aboriginal reserves are to be inspected in the Alice Springs area before the close of the main reconnaissance.

A soil map and report for the Tatiara district in the upper south-east, surveyed earlier, have now been compiled for publication. In connexion with investigations by the Soil Physics Section (*see* Section 4 (b)) a reconnaissance inspection of an area south-east of Meningie was made in the first place to determine the local soil features and the problems involved in the soil moisture investigations, and to select experimental sites. In County Grey, a recent reconnaissance soil survey of 2,044 square miles, completed in periods totalling ten weeks of field work, represents the latest approach to such broad mapping using data from detailed surveys as a working basis. The report from this survey will furnish an up-to-date account of the soils and land use in a most productive part of South Australia. It is expected that a more accurate soil map of south-eastern South Australia will be completed within two years following this principle, as a large amount of information on unit areas is available.

(*c*) *Tasmania.*—The regional survey which has as its objective a new soil map of Tasmania has been continued with the addition of units in the Buckland, Snow Hill, and Tooms rectangles. This year a series of Divisional Reports has been initiated, under the general title "Reconnaissance Soil Map of Tasmania". Each report contains one sheet of the map, representing an area of approximately 420 square miles at a scale of one inch to one mile. Brief outlines of the soil groups and of their present and potential use are given. Three reports of the series have been issued this year.

In the Launceston Basin a further study has been made of the evolution of the landscape to its present form. The area offers good possibilities for the correlation of land surfaces with phases of the Pleistocene epoch and of the ages of these surfaces with the degree of profile development of soils upon them. It is this part of the State which has the largest extent of soils climatically and topographically suited to the development of systems of agriculture using spray irrigation on a comparatively small scale as a supplement to the natural rainfall.

Field work for the survey of the Burnie-Table Cape area has been completed and a report is in preparation. Recent work by the Department of Agriculture has confirmed the earlier indications of a widespread deficiency of cobalt in the basaltic soils. Preliminary analyses of soils and the parent rock indicate that though the basalts are well supplied with cobalt, the majority of it is removed in the processes of soil formation. Further studies of the cobalt status of these soils are needed, as also is an assessment of the relative cobalt status of the various groups of basaltic soils defined in soil surveys both in this area and elsewhere in the State.

(*d*) *South-east Region.*—Field work has been carried out in several districts with emphasis more on an understanding of the principles governing soils properties and distribution, rather than mapping the full detail of soil series or associations.

In the Riverine Plain of south-eastern Australia a theory of depositional layers of water-laid or wind-blown origin has been developed which is proving of considerable value in solving problems in irrigation, salinity, and waterlogging common in that region. The study now completed in the Griffith-Yenda district has shown the relation between soil origin, depositional layers, and irrigation. The same principles apply to the Lower Murrakool, an area proposed for irrigation in New South Wales near Swan Hill and currently being surveyed. The soils have been formed in part on the sand dune systems, and in part on Riverine Plain materials. Parna (loess-like material) is distributed over most of the area. Erosive phases in the past have had a marked effect on the pattern of variability of the soils. This study is still in progress.

Near Canberra the study of terraces and the soils developed on them has progressed to the point where the theory of origin and details of character can be stated. As a specific case depositional layers in the Lyneham-Dickson section of Canberra City are being shown as related to the suitability of the area for a housing project. This work is proceeding and reveals several highly plastic layers which are old buried soils in the country, and these are likely to be highly significant for the purpose in hand.

A reconnaissance of the south coast region in New South Wales has been made, defining the soils and landscapes from Port Hacking to Narooma. There is a great variety of soils here, their characteristics being governed largely by age and by parent rock type; age in turn is related to landscape. There is a great diversity in fertility also among them, and further study in this regard should be facilitated by the primary survey. This region appears capable of a great deal more useful development.

A reconnaissance of the soils of the Wagga District in New South Wales has been commenced. This district is central to the south-western wheat-growing areas, and these studies in soils and landscape may serve as a useful basis for parallel investigations in soil fertility.

The work in soil microscopy is continuing and being developed to study some of the problems of soil processes and micromorphology. Studies have been completed on the effect of oriented clay on soil aggregate breakdown and soil consistence, and also on the experimental development of oriented clay in soil materials. Mineralogical and fabric studies on soils from Tasmania, Queensland, and South Australia have been made as a service to soil workers in those studies.

(*e*) *Queensland Region.*—Soil and Land Use Reports and maps covering the Darling Downs project (approximately 1,100 square miles) have been prepared for publication. To assist interpretation of the soils for the pedological report now being compiled, clay fractions of the more interesting red and black soils have been examined by the Division's Mineralogy Section.

By the end of the 1955 season the regional soil survey had covered 26,000 square miles comprising the southern half of the Brisbane sheet, Australian Geographical Series maps. A report and map covering this unit are in preparation. Most of the important groups of Queensland soils are represented in the area which includes, in the south-western corner, several thousand square miles of heavy clay soils of the brigalow country. These lands constitute one of the most important under-developed resources of the State, having a high potential for sheep raising and extensive cropping.

A detailed soil survey has been made of 140 acres of the Commonwealth Scientific and Industrial Research Organization's Samford Experiment Farm to define the soil pattern for experimental purposes. In general the soils are very variable in character and the soil pattern is a complex one. Several types contain considerable amounts of ferro-manganiferous nodules. Mapping of another Commonwealth Scientific and Industrial Research Organization experimental area in the coastal lowlands north of Brisbane will be completed shortly.

(*f*) *Northern Australia.*—An officer of this section has been seconded to the Land Research and Regional Survey Section for extensive survey work in New Guinea and North and Central Australia.

3. SOIL CHEMISTRY.

(Division of Soils.)

(*a*) *Pedological Studies.*—The chemical study of the interrelationships of terra rossa and rendzina soils of South Australia has been completed and written up for publication. Because the range of values for any characteristic of one group overlapped that for the other it was considered that these two groups of soils form part of a continuous sequence with a steady progression in colour from black to red on one hand and black to grey on the other. This sequence could be subdivided into red, brown, grey, or black members in a manner analogous to the subdivision of podzolic soils. It was therefore suggested that all profiles having a shallow to moderately shallow solum and no marked textural differentiation throughout, and overlying calcareous material, be designated *terracal*, with a qualifying term to describe particular profiles, e.g., red terracal, brown terracal, black terracal. Similar soils from other parts of the world are now being examined to see whether these conclusions apply generally.

(*b*) *Geochemistry of Soils.*—Geochemical work has begun in attempting to relate certain soils of the south-east of South Australia to the underlying volcanic materials from which they have been formed. At present the older volcanics of the Mt. Burr Forest are being studied. The distribution of eighteen elements in the parent materials, soil profiles, and the clays separated from different horizons of these profiles is being examined by spectrochemical and chemical methods to determine their redistribution under the influence of the different processes of soil formation. The use of total zirconium (determined spectrochemically) as an index of weathering has enabled some broad trends to be discerned, but full interpretation is hampered by lack of homogeneity in some profiles and possible movement of zirconium down the profile. The mode of transfer of essential nutrients from the weathering tuff to the overlying sands is being studied. This is of importance in the nutrition of the pine forests.

(*c*) *Spectrochemical Investigations.*—The study of the distribution of trace elements in red-brown earth profiles has been continued. From an examination of the distribution of the individual elements in the profile and the variation of these elements between profiles it was shown that the six elements studied could be arranged in order of decreasing mobility in these soils, namely, cobalt, copper, gallium, vanadium, molybdenum, manganese. This order was confirmed in one profile in which it was possible to compare the amounts of the element in the weathering shale (parent material) with the amounts in the overlying soil.

In any one profile the concentrations of each element, except manganese, were correlated with the clay contents of the horizons. However, considering the surface horizons of all profiles only gallium, vanadium, and molybdenum could be correlated with the amount of clay. During the course of this work it was established that no significant loss of these elements occurred when the clay was given mild chemical treatment during its dispersion and separation from the soil.

There is now considerable confidence in the techniques developed for the spectrochemical analysis of refractory materials such as soils and plant ash, and the precision and accuracy of these methods have been established. In their current form the techniques are now being written up in detail for publication. Three methods of control of arc current in excitation of mineral powders are commonly used in spectrographic laboratories but their relative efficiencies had never been precisely assessed. Continuous manual control of the arcing current and "initial adjustment without further control" gave the same precision in analytical results for elements of low and medium volatility. However, continuous control gave increased precision for non-volatile elements. During the course of this work it was noted that the ratio of line intensities for copper and silver was less reproducible with continuous current control. Results such as this indicate that good practices in metallurgical spectrography are not necessarily sound for the analysis of mineral powders. It was also noted that the volatilization curve for manganese, determined by the conventional procedure from an arc line, differed from that determined from a spark line. This indicated that the volatilization curve does not represent the manner in which the element enters the arc discharge, as has been generally assumed.

A great improvement has been effected in the arcing of sandy soils by the addition of a small amount of potassium sulphate. Addition of as little as one fifth of the sample weight gave satisfactory excitation; variability was greatly reduced and there was no noticeable effect on the limits of detection of the elements of interest.

(*d*) *Uptake of Micronutrient Metals by Plants.*—Experiments have continued on the residual value of some oxides of manganese to oats. It was found that the residual value of a highly available manganous manganite was greater and more persistent in one soil under alkaline conditions than in the same soil at pH 6–6.5. This may be interpreted as evidence for a fixation mechanism involving reduction and reoxidation rather than one resulting from aging of oxide structures, as has been previously suggested. Such a mechanism would also explain why manganous sulphate added to a soil of the type used has a lower immediate value and lower residual value than the equivalent amount of some precipitated oxides.

(*e*) *Physical Chemistry of the Soil.* (i) *Soil pH Mechanisms.*—The commonest single determination made on soils is their reaction (pH) denoting degrees of acidity or alkalinity. The measurement of pH is controversial, and fundamental work is necessary to clarify ideas on the mechanisms involved and define what is being measured. The following researches have been carried on with these objects in view.

Work on ion exchange-pH relationships has been done both in Adelaide and at Wageningen, Holland, during an overseas visit by the officer concerned, to elucidate further the processes involved in determining the pH of a soil.

Dialysis of sodium saturated soils against hydrogen saturated ion-exchange resin has been used to secure a range of acid soils without the production of an accompanying salt, and additional experimental data have been obtained from dialysis studies on these. In acid dialysates the amount of silicon released into solution was not dependent on the quantity of sodium in solution nor on the amount of exchangeable sodium in the soil. Neither was there any relationship between the amounts of sodium in the dialysates and their pH. In acid dialysates, however, the pH and the silicon in solution were dependent on one another in a way which varied slightly with the concentrations of the soil suspensions. In alkaline dialysates the silicon in solution, after a sudden drop at pH 7 to about one-sixth of its value in the acid dialysates, remains at a constant value of about 3×10^{-5}M up to about pH 10. After this the quantity of silicon in solution increases in a similar way to that predicted by calculations from the first and second dissociation constants of silicic acid.

(ii) *Exchangeable Ion Equilibria in Soils.*—In most pedological studies a knowledge of the ion-exchange capacity and exchangeable hydrogen is most important, yet there is no generally acceptable definition of these quantities among soil workers. Investigations into the calcium hydroxide-nitrophenol and alternative buffer systems with pH values near 7 have shown that experimentally determined values for exchangeable hydrogen to pH 7 varied within rather wide limits depending on the valency of the cation and the concentration of the solution. Since the choice of a technique is arbitrary it may well be decided by its suitability for inclusion in a comprehensive system of exchange analyses. For this the use of an unbuffered equilibrating solution is attractive. The titration of the residual alkali at equilibrium is simple and accurate. For preliminary work, ammonium chloride with a small excess of ammonia is being used, and a tentative method has been worked out. The net negative charge on the soil colloids at the final equilibrium pH can be determined within limitations for which a solution is being sought. The technique has given good results for cation-exchange resins and soils.

(*f*) *Rainwater Studies.*—Analysis of samples of rainwater collected in association with the Soil Conservation Authority of Victoria and of others from South Australia has continued, and the pattern of variation in composition with season and with distance from the coast is becoming clear. In connexion with the studies of the accession of soluble materials to the surface of soils, two lagoons in the Barossa District of South Australia have been studied. Samples of water have been collected and analysed at monthly intervals, and at the same time the levels of the lagoons have been recorded. Work on the balance between material brought in by rain and that lost by drainage is being continued in other areas where river gaugings are available.

(*g*) *Miscellaneous.*—Miscellaneous investigations have included the analyses of soils from the Adelaide Hills for their iodine content, the study of changes in the salts and exchangeable cations in the soil used for a rice cultivation experiment, the examination of samples obtained from deep bores associated with the King-street–South Melbourne bridge, and the examination of soils from the Mount Crawford Forest in connexion with the poor growth of pines.

Methods of analysis have continued to receive critical attention. Improvements have been effected in the determination of small amounts of sulphate by back titration of excess barium with ethylenediaminetetraacetate, and an alternative method for the determination of free ferric oxide in soils has been examined. Flame photometers have been further studied. Their stability has been increased, and interferences from other elements have been considerably reduced. During the year a Christy and Norris impact mill was modified to make it entirely suitable for grinding plant samples without introducing any iron contamination. It is now possible to determine copper, molybdenum, iron, and other trace metals in the same sample.

(*h*) *Queensland Region.*—Research work has centred entirely on some chemical properties of illuvial podzol horizons. The extraction of organic matter from this type of soil with organic reagents has been examined in some detail. The proportion of total organic matter extracted with acetylacetone varies with the soil, but averages 70 per cent. Extraction is accompanied by varying amounts of iron and aluminium of which some originates from hydrous oxides or clay minerals and some is responsible for holding the organic matter insoluble in the soil profile. It has been shown that the metal-organic matter bonds are probably ionic in character. Potentiometric titrations of acetylacetone-treated extracts, in presence of iron, aluminium, or copper, show no evidence of chelate formation. Some results indicate that iron may be less important than aluminium in the illuviation process, and further work on this aspect is in progress.

(*i*) *South-east Region.*—The principal research has concerned soil phosphorus. Several compounds of iron and aluminium with phosphate have been prepared in the laboratory under varying conditions and these are being examined by optical and X-ray techniques and their physico-chemical properties determined. Some of these compounds have also been examined in regard to their capacity to supply phosphorus to plants. The adsorption of phosphate on the surface of iron and aluminium oxide concretions and films in soils is also being investigated. A more sensitive method for the determination of extremely small amounts of phosphate has been developed.

Geochemical work on soil profiles of the alpine humus group has revealed some interesting differences in ultimate weathering of felspathic minerals proceeding from higher to lower levels of the landscape following a progression to podzolic soil types.

(*j*) *Western Australian Region.*—More complete knowledge of the characteristics of soils derived from lateritic formations has been sought in recent years. Analytical data on the chemistry of thirteen typical lateritic soils have been assembled. Co-operative work by the Department of Physics, University of Western Australia, on clay mineral composition by X-ray methods has reached finality. These represent the first full study of a large and diverse group of lateritic soils in Australia.

4. SOIL PHYSICS.

(Division of Soils.)

(*a*) *Field Measurement of Water Content of the Soil.*—A method using neutron scattering as a function of soil water content has been used to follow seasonal soil moisture changes for almost two years, with good success. The technique still needs to be improved to enable measurements to be made near the surface of the soil. It is probable that this can be done and work is being directed to that end. A paper has been published, which shows that calibration of the instrument may be helped considerably by a resort to neutron diffusion theory. This calibration refers to the probe (and neutron source) being enclosed in an effectively infinite medium. For measurements near the surface of the soil this calibration is not valid, and calibration to suit the geometry of a semi-infinite medium will be attempted.

A satisfactory mobile unit has been designed by the South Australian Department of Mines to the Division's specifications.

(*b*) *Measurement of Evaporative Losses from Soil.*—In development of the upper south-east of South Australia the question has been raised whether the evaporation from the present natural heath vegetation is different from that to be expected when the land is cleared and sown to pasture. The supplies of stock water in the test area come from underground shallow aquifers, apparently fed by drainage from the small excess of rainfall over evaporation in the winter months, and it is important that these supplies should be recharged seasonally. Therefore measurements are being made on the soil water storage at two sites in and near the area, which have been selected as representing the two conditions of land cover, viz., natural heath and sown pasture. The Division is co-operating with the Department of Mines, South Australia, in this work. The depth and quality of water in holes at the experimental site are being followed by the Department.

Evaporation is calculated from measurements by the neutron moisture meter of changes in amount of water stored in soil and amount received as rainfall. Evaporation may also be obtained from meteorological data, if a theory of the nature of the transfer of water vapour to the atmosphere be used quantitatively. A comparison of the values for evaporation given by the two methods is being made. The limit on evaporation rate imposed by lack of free water when the soil is drying is also being studied.

Other measurements of losses and gains of water in soil are being conducted in relation to moisture changes under houses. This is a long-term study which has been reported upon previously.

(*c*) *Saturated Permeability of the Soil and Land Drainage.*—An officer of the Soil Physics Section worked for ten months with the A.R.C. Unit of Soil Physics in Cambridge, England, concerned among other things, with the physics of land drainage. Methods for the measurement of soil permeability in the field were studied, which included the two-well method of Childs and the Kirkham-type piezometer tube method. A combination of results from these two methods allows a quantitative description of soil anisotropy to be made. Of eleven sites where permeability was measured, the soil was measurably anisotropic for permeability at six sites.

(*d*) *Permeability of Soil.*—Measurements of permeability in a column of soil at water contents ranging from approximately field capacity to wilting percentage have been obtained by a technique of supplying water under tension to one end of the soil column and allowing evaporation to take place at the other end. This technique has now been refined to enable the evaporation conditions to be varied more readily, and to allow the evaporation rate to be measured, so that equality of evaporation rate with rate of intake of water, together with constant readings of water tension within the column, determines when the steady-flow state is taking place. The same apparatus will be used to determine, on a laboratory scale, the soil structure factors which govern the loss of water from soil under fallow conditions and ways in which this loss may be reduced.

(*e*) *Swelling.*—A comparison is being made between the swelling of a clay mineral, calcium-saturated montmorillonite, and the swelling of soil clays. The film thickness for a soil clay (illite), obtained by dividing the volume swelling by the surface area, as determined by nitrogen adsorption, is approximately 20Å. This compares with 5Å in the fully swollen calcium montmorillonite. The reason for this difference is being investigated.

(*f*) *Surface Area of Soils.*—The negative adsorption of chloride ions by sodium and potassium clays has been used to measure the surface area of these materials. The surface areas obtained by these methods are in good agreement with those obtained from low temperature nitrogen isotherms. For montmorillonites the potassium ion is used, since the internal separation of the elementary silicate sheets making up a crystal never exceeds 5.4Å. The volume from which chloride ions are excluded by negative adsorption varies with the concentration of the electrolyte solution. This variation can be used to calculate the external surface of the clay.

This method has been used to study the effect of pretreatment on the external surface of bentonite. With moderate shaking it has been possible to vary the measured external surface from an initial 20 m^2/g to 200 m^2/g. The total surface (internal and external) is known from the structure of the clay mineral to be 760 m^2/g. The water vapour adsorption isotherms of a number of clay minerals are being examined in relation to surface area and exchangeable cations.

(*g*) *Stability of Soil Aggregates.*—Work concerning the effect of initial water content and energy condition in the soil water on the stability of soil aggregates, has been undertaken. The important factor in breakdown of aggregates is the rate of wetting. Aggregates which are unstable when wetted suddenly can be made stable by wetting slowly before immersion in water.

Aggregates show signs of failure when wet under tension at a sufficiently rapid rate. The increased rate of wetting caused planes of failure which accommodated the additional water. The breakdown of aggregates is small if they are previously wet slowly to a tension of 100 cm. or less before immersion in water. Dry clay soil aggregates were not stable when wet under vacuum because the high rate of wetting caused differential swelling.

Aggregates from virgin loam soil were completely stable when immersed in water whereas those from the same cultivated soil broke down completely. In this loam soil there appeared to be a relation between mechanical strength of the dry aggregate and stability of the aggregate in water.

(*h*) *Mechanism of the Action of Soil Stabilizers.*—Viscosity measurements have shown that the "Krilium" molecule will not pass through 10-micron diameter pores in a sintered glass filter. Since soil pores would also be negatively charged it can be inferred that "Krilium" does not enter these pores. It is thought that "Krilium" acts in the same way as organic matter and is precipitated by calcium in the large soil pores. Soil aggregates from a continuously cultivated red-brown earth soil have been treated with "Krilium" and have been found to have properties very similar to the virgin soil aggregates.

(*i*) *Soil Tillage.*—It has been found that after several years of pasture at the Waite Institute, Adelaide, a well-defined profile of soil aggregate stability is developed in the top six inches of the soil, the surface two inches being often ten times as stable as that at six inches. A field experiment using three types of plough—disc, mould board, and chisel—at three depths of ploughing, has been begun to determine the extent of profile disturbance by these tillage treatments and its effect on crop behaviour.

(*j*) *Miscellaneous.*—A number of measurements of soil physical properties have been undertaken and advice has been given on equipment for other laboratories. Enquiries have been handled concerning soil drainage, water-proofing of dams, run-off of water from soil, and soil temperature and moisture distribution in relation to electrical power lines.

(*k*) *Queensland Region.* (i) *Darling Downs Area.*—The characterization of samples arising from surveys on the Darling Downs project has been completed. These samples cover the chief soils occurring in the area, and an analysis of the results has been made to tie in the laboratory results with what is known of the agricultural performance of the soils. The application of a physical index to rate the soils has been tested further on these results.

(ii) *Organic Matter in Soils.*—Considerable attention has been devoted to a study of the density of organic matter occurring in soils. Differences in density are quite marked and vary with position of organic matter in the profile. The highest densities are associated with organic matter that has been mobilized, especially as represented by organic matter accumulated in illuvial horizons of podzolic soils. Although changes in carbon content appear to accompany the density increases, further work is required to establish whether density changes are due solely to structural rearrangements in the organic material or rather to some association of metals with the organic material after it has reached a particular state of decomposition. Nevertheless, the difference in density appears to offer some promise as a means of fractionating the different forms of organic matter in soils.

The role of organic matter in increasing the water stability of structural aggregates has been investigated for soil material from the fragipan of a ground-water podzol. This material, being completely siliceous even in the colloidal fraction, and of relatively uniform composition, is a suitable medium for studies where the complicating effects of clay minerals can be eliminated. The highly decomposed organic matter as it occurs in these soils does not seem to act as a bonding agent, but rather by coating the individual particles to confer a hydrophobic character to the surfaces. This results in slower rates of wetting and consequently an ability to withstand disintegration upon sudden wetting.

(iii) *Structure Alteration in Cultivated Soils.*—Work has continued to establish a suitable method of structure assessment in connexion with effects of cultivation. The results of compression of small samples have been studied. A cultivation experiment examining the effects of three different depths of cultivation has been laid down on Mywybilla clay, a poorer-structured soil of extensive area occurring on the plains section of the Darling Downs.

(iv) *Water Content Changes in Natural Soils.*—Observations have been continued on the joint project with the Ecology Section, Division of Plant Industry, in the Lismore district, New South Wales. A stream gauge, which provides a control measure on the other hydrological information being collected, has been brought into operation and continuous measurement of discharge from the experimental watershed is obtained. Some difficulties in the ability of various soil moisture measuring devices to withstand exposure have been met.

Preliminary measurements to estimate transpiration from trees, mainly rain-forest species, have been commenced, and to ascertain the relationship of transpiration to meteorological environment and soil moisture.

(*l*) *South-eastern Region.* (i) *The Effect of Rice-growing on Physical Properties of Soils.*—The long-term effect of rice-growing on a red-brown earth and a grey soil of heavy texture from the Murrumbidgee Irrigation Areas has been examined. After 28 years of periodic rice culture with up to eight crops only very small increases in aeration, range of available water, and degree of clay aggregation are evident. In general no major cumulative effect is indicated.

(ii) *Entrapped Air as a Factor in the Breakdown of Fine-textured Aggregates.*—The rate and degree of disruption of rapidly wetted soil crumbs were measured in air and in vacuum as part of a project to correlate the various factors contributing to breakdown of aggregates in fine-textured soils. The results presented show that for the soils concerned, entrapped air is playing a negligible part compared with the swelling forces of oriented clay films.

(iii) *Temperature and the Dispersion of Soil Crumbs.*—The effect of temperature on the rate and degree of dispersion of crumbs from six soil types exhibiting a range of textures and stabilities is being studied. Methods have been developed to measure dispersion with a minimum of mechanical disturbance. Low concentrations of particles smaller than 20 μ in suspension have been measured by means of a spectrophotometer and appropriate calibration curves. Large variations in rate of dispersion have been found between soils and large differences in the effect that a change in temperature has on this rate from soil to soil. The total amount of dispersion after 12 hr. at 10° C. is significantly less than that after 12 hr. at 40° C.

(iv) *Parna Identification.*—Various methods of particle size analysis, including that of the bottom withdrawal tube, are being used in an effort to find an index for characterizing the different parna layers occurring in the Riverine Plain. Preliminary results show that the silt-clay ratio may be useful for identifying some loess-like strata.

(v) *General.*—During the year standard physical measurements have been made on projects involving research of the Pedology and Soil Mechanics Sections. Collaboration involving supervision and demonstration of techniques with a research team from the New South Wales University of Technology has been given in their cultivation experiment at Wagga Research Farm.

5. SOIL MICROBIOLOGY.

(Division of Soils.)

(*a*) *Phosphates and Soil Microorganisms.*—Research has been directed to soil phosphates parallel to work in other Sections. The availability of naturally occurring or synthetic phosphates can be tested microbiologically on very small quantities and more quickly than by using plants.

The present research has been divided into two projects, one dealing with the microbial assay of available phosphates, the other with the mechanisms of solubilizing phosphates.

(i) *Availability of Phosphatic Materials.*—This work was undertaken to find whether soil microorganisms have similar difficulties in obtaining fixed phosphates as do plants growing in certain soils. Two dissimilar fungi were used for bioassaying available phosphates, viz. *Aspergillus niger* which produces organic acids and *Curvularia geniculata* which maintains neutral conditions. In addition assaying was carried out using the soil's own mixed microflora by comparing the respiration in the presence of phosphates differing in availability. Assays have been completed for 61 mineral phosphates very few of which have been detected in soil as yet. Of those which might occur in soil the most unavailable were apatites, strengite, dufrenite, variscite, and some leucophosphites. Seventeen organic phosphates have been tested and of these only ferric phytate was poorly available, but not sufficiently so to account for the slow mineralization of phosphate from soil humus. The availability to microorganisms of phosphates adsorbed on to 20 clays and sesquioxides was surprisingly high. The influence of particle size, of period of aging, and of pH was also studied. In general *Aspergillus niger* was able to procure more phosphate from insoluble sources than the general microflora, which in turn was better than *Curvularia geniculata.* Microorganisms seem to possess better mechanisms for obtaining fixed phosphates than most plants.

(ii) *Mechanisms of Releasing Phosphates.*—Over 50 soils have been examined for the presence of bacteria, actinomycetes, and fungi capable of rendering calcium phosphates soluble, but they were detected in five soils only, most of which were acidic. The rhizosphere organisms from over 50 plants were also examined but none were detected. This is contrary to the findings of Gerretsen in Holland who used an excessively sensitive medium. Acid producing fungi dissolved much more calcium phosphate than acid forming bacteria. Lactobacilli associated with dental caries solubilized brushite but not apatite, strengite, or variscite. *Aspergillus niger* dissolved brushite and apatite. Eighteen bacterial strains were isolated which attacked calcium phosphate at first, but many lost the capacity after a few subcultures while some even reprecipitated calcium salts. One bacterium, a pseudomonad isolated from peat, was selected for detailed study of the mechanism of releasing phosphate from brushite. Solubilization occurred only when grown on sugars which produced acids, some of which were volatile and others non-volatile. Chromatography revealed the presence of lactic acid in greatest quantity, acetic acid in small amounts, and possibly traces of propionic, glycollic, and citric acids. This pseudo-monad was unable to dissolve apatite suspended in agar.

(*b*) Rhizobium *Studies.*—Cytological studies have been made upon strains of *Rhizobium trifolii* associated with clovers and strains of rhizobia isolated from indigenous and naturalized alien legumes. Endospore formation has been found to be a general phenomenon, usually associated with the rough, non-gummy phase, but occasionally with the smooth, gummy phase. Sporulation enabled the organism to resist heat, and many cultures remained viable after 20 min. at 100° C. The progeny of such resistant spores of clover strains produced nodules on subterranean clover plants grown under aseptic conditions in test tubes. The sporing phase may be important in the persistence of the organism in soil under adverse conditions.

Serological studies have been continued with a view to establishing antigenic relationships between strains and spores, and in order to follow the fate of strains inoculated on to seed sown in soil containing other strains of rhizobia.

(*c*) *Fractionation of Soil Humus.*—The nature of humus and processes leading to its formation have long been the subject of research since humus enters into the chemistry of the soil affecting plant nutrition. The following investigation is directed at the nitrogen fraction of the humus.

A large continuous electrophoresis apparatus was built to fractionate humates, but consistent results could not be obtained because it was impossible to stabilize pH, temperature, and outflow, despite numerous trials with several buffers flowing at various rates through the electrode vessels, different voltages, different heads of pressure, and varying particle size. Instead, fractions were obtained by multiple paper electrophoresis, but no proteins were detected and no marked concentration of nitrogenous substances occurred, although amino acids were present in acid hydrolysates. Experiments have been started to follow the fate of proteins during the composting of buffalo grass, lucerne, and compressed yeast.

(*d*) *Oxidation of Hydrocarbons by Soil Bacteria.*—Work on the stimulation of oxidation of *n*-decane by monovalent cations using *Corynebacterium* sp. has been extended to other hydrocarbons and their derivatives. Using resting cells harvested from a medium deficient in potassium ions, it was shown that 0.0008M potassium ions in 7 hr. increased oxygen consumption in presence of *n*-hexadecane, *n*-tetradecane, *n*-decane, and *n*-octane by 231, 108, 122, and 190 per cent. respectively. With *n*-hexadecane and *n*-decane, ammonium ions were as effective as potassium ions, with, rubidium ions less so, but caesium, lithium, and sodium ions were without effect. The rates of oxidation of aliphatic monohydric alcohols (range ethanol to undecyl alcohol) and of the monocarboxylic acids (range acetic to *n*-decylic) were unaffected by the addition of potassium ions; this suggested that potassium ions exert their influence before the formation of alcohols and acids. Two different corynebacteria showed this potassium stimulation more on lyophilized cells than fresh cells.

(*e*) *"Spindle Stand" of Pines.*—Pot experiments have been completed on the possible cause(s) of "spindle stand" in *Pinus radiata* growing in Young sand from Mount Burr. The unthrifty appearance of the pines could not be improved by providing more water, more mycorrhiza, or more needle litter, nor by eliminating possible toxic factors with clays, lime, ethylenediamine-tetra-acetate, or leaching. Vigorous, healthy pines could be obtained by applying fertilizers containing nitrogen, phosphorus, sulphur, potassium, zinc, and copper. The addition of over 50 other elements produced no further beneficial effects after a year. It is thought that "spindle stand" might be due to a multiple deficiency of essential elements, and it is doubtful whether it would be economically sound to apply fertilizers and establish pines on such a deficient sand.

(*f*) *Rhizosphere.*—An investigation has been started on the influence of light intensity upon the exudation of organic substances from plant roots and their effect on rhizosphere microorganisms.

6. Clay Mineralogy.

(Division of Soils.)

A single-crystal and a Weissenberg camera have been installed. These cameras will be used for studying the structures of clays and related minerals and for following in detail the structural changes involved as rock minerals weather to clays. The Raymax X-ray unit has been modified to incorporate electrostatic focusing of the electron beam with an improvement in focus and increased emission stability. The replacement of the old-type vacuum seals of this unit with neoprene rings and the incorporation of vacuum valves has improved its operation.

Recently a member of the Section returned after spending two years at the Cavendish Laboratory, Cambridge, and one year at Pennsylvania State University. At Cambridge the calcium felspar, anorthite, was studied in an attempt to determine the atomic parameters as precisely as possible. It was necessary to use three dimensional X-ray data to give the required accuracy in the parameters, and this coupled with the low symmetry (triclinic) and large unit cell has made the analysis of the structure difficult. The electronic computer, EDSAC, was used in calculating structure factors, and a Hollerith punched card machine for the Fourier syntheses. During the course of the calculations two desk computers were designed for general use in calculating geometrical structure factors for space groups of low symmetry.

At Pennsylvania State University a preliminary study was made of the weathering of felspars to clay minerals. Attempts were made to alter single felspar crystals to clays in hydrothermal bombs. It proved difficult to find conditions for producing layer lattice minerals from felspars alone. The experiments suggest that felspars break down completely before being reconstituted to clays.

(*a*) *Phosphate Minerals.*—Some soils although naturally high in phosphorus behave towards plants as if phosphorus deficient. Other soils render unavailable much of the phosphorus which is added as superphosphate. It is probable that the naturally unavailable and the fixed phosphates are related, and a knowledge of their nature is desirable. Phosphates in soils are divided into organic, adsorbed, and mineral forms, but more specific information on them has been difficult to obtain—largely because of the small amounts in the soil. Using refined X-ray diffraction techniques some naturally occurring phosphates have been identified as belonging to the gorceixite ($BaAl_3(PO_4)_2(OH)_5.H_2O$, $CeAl_3(PO_4)_2(OH)_6$) florencite series. These were concentrated in the 0.5–5 micron fraction of the soils and could be obtained almost pure by dissolving the silicate minerals in hydrofluoric acid. The density of the minerals was confirmed on these concentrates by analyses for phosphorus, barium, and rare earths. These minerals have been extracted from soils from Queensland, New South Wales, and South Australia, so that, although unexpected, they are not to be regarded as oddities. In some of the soils more than 70 per cent. of the total phosphorus was present as one of the above minerals. The extreme insolubility of these phosphates is demonstrated by their occurrence in very highly weathered soils. The technique of concentrating in hydrofluoric acid bears this out. Micro-biological assay of these minerals, extracted from soils, indicated that their phosphorus is extremely unavailable. The nature and occurrence of the minerals suggest that they are an active part of the soil profile and not just a residual of parent material.

In conjunction with studies in the Chemistry and Microbiology Sections many phosphate minerals were checked for identity and purity.

(*b*) *Soil and Other Analyses.*—Detailed mineralogical examination of the clays of a large group of soils from the Barossa Valley, South Australia, has been carried out in connexion with the soil survey of the area. Other clays from Northern Territory, New South Wales, and Queensland have been analysed. Clays from soils and various minerals from the Antarctic have been identified for the Antarctic Survey and at the request of Sir Douglas Mawson.

In the analysis of clays from many parts of Australia illite is found to be a major component. Yet many of these clays differ considerably in physical and chemical properties. It is suspected that the behaviour of clay illite is markedly dependent on the amount of hydration it has undergone. Such properties as swelling and potassium fixation would be related to its hydration. A technique has been developed for investigating the low angle scattering of clays using the Phillips diffractometer, and it is hoped that these studies will enable a distinction to be made between the various illites.

(*c*) *Fluorescent X-ray Spectroscopy.*—This technique has been developed further with increased accuracy and sensitivity. Under suitable conditions an accuracy of 2 per cent. can be attained, without the use of internal standards, while for some elements concentrations as low as five parts per million can be measured. During the year various soils have been analysed for iron, titanium, zinc, zirconium, copper, strontium, praseodymium, neodymium, and barium while plant and liver specimens have been analysed for iron, copper, and zinc. The latter analyses have been made with the co-operation of officers of the Division of Biochemistry and General Nutrition who are interested to see if the technique is suitable for biological specimens. The X-ray analyses of these specimens agreed well with results obtained by conventional chemical methods. The X-ray technique is much quicker and involves almost no pretreatment of the sample.

7. Soil Mechanics.

(Division of Soils.)

The subject of soil mechanics, as a branch of civil engineering, relates to a form of land use totally different from that associated with the normal disciplines of soil science. However, many forms of engineering land use are dependent upon the same soils and the same soil properties as those studied for agriculture. In particular, the problems of design of roads and airfields and of shallow foundations for small buildings are closely associated with the *in situ* characteristics of natural soils. The establishment of a Soil Mechanics Section within the Division provides the opportunity for collaboration between the research workers engaged on the study of the soil *per se*, and on the applied problems of soil mechanics. Other sections of the Division participate directly or indirectly in the latter work.

An exceedingly wide range of foundation problems, related both to domestic buildings and engineering structures, has been noted within Australia. This range is logically related to the diversity of soils, of forms of building, and above all of environmental conditions throughout the country. Failures of buildings of all traditional types have been noted on various clay soils in every State—due presumably to the seasonal phenomenon of shrinking and swelling. Other failures of domestic and industrial buildings have been attributed to the consolidation process, and some soils of exceptionally low bearing capacity have been noted.

In view of the limited recorded knowledge of the engineering characteristics of Australian soils, it is extremely desirable that these field investigations should be carried out as comprehensively as possible to form the basis for applications of known engineering principles and to define necessary research. Some considerable attention has been devoted to the development of new procedures to obtain a reasonable body of data. Emphasis has been placed on three aspects of this programme, viz.:—(i) the classification of foundation problems; (ii) the development of efficient field techniques; (iii) the encouragement of the use of proper soil sampling techniques.

(*a*) *A Regional Classification of Foundation Problems.*—From accumulated experience on the nature of soils and problems of associated building structures an attempt has been made to classify foundation problems regionally in areas with soil formations of comparable engineering properties such as estuarine muds (South Melbourne), clay soils with high swelling characteristics (North Melbourne), or relatively stable soils (East Melbourne).

Regional foundation problems may relate to small areas of highly developed land as in cities or to large areas of land in which building activity is sparse. An example of the latter type is to be found in the Wimmera region of Victoria in which area almost every sizable building on the characteristic heavy grey clay has suffered appreciable damage owing to foundation movements.

A total of about twenty regional foundation problems is now recognized in Australia. It is hoped that, by suitable classification of techniques, the number of problems although probably increasing in number may be kept within workable bounds.

(*b*) *The Development of Efficient Field Techniques for Soil Sampling and Testing.*—An attempt has been made to develop mobile apparatus which would permit a research team in the field to undertake within a short period the complete evaluation of the foundation characteristics of any soil. As complementary equipment to a power-operated soil auger and a mobile laboratory containing a triaxial shear test machine, apparatus has been developed for two principal purposes: (i) to sample directly into consolidometer rings, and (ii) to undertake consolidation tests adjacent to the field site. For the latter purpose a lightweight three-unit consolidometer has been constructed and techniques for rapid completion of a loading cycle have been investigated. This equipment is now operating satisfactorily in the field but improvements in design are proposed.

Various methods of obtaining undisturbed soil samples are being investigated. It is hoped that standard procedures may be introduced to suit normal soil conditions throughout Australia.

(*c*) *Regional Soil Studies.*—A study of the foundation characteristics of the soils of the proposed township of Elizabeth, South Australia, has been commenced. This town, with an estimated potential population of 50,000, will be built on an alluvial plain to the north of Adelaide. Foundation problems expected are those associated with clay soils exposed to a marked seasonal moisture cycle. Buildings will be both domestic and industrial. The experimental programme, now in its early stages, will involve, for each major soil type, the measurement of the shear strength of the soil at limiting moisture conditions, settlement due to load, and seasonal movements of the soil (covered and uncovered) and of adjacent buildings.

Two pieces of work completed at Adelaide were centred in the suburbs of Broadview Gardens, in which War Service Homes have large building interests, and Northfield where the State has under design extensions to the mental hospital. In the former, trouble developed owing to consolidation under buildings from a variable saturation of the soil close to the surface which was ascribable to the presence at a depth of 2-10 feet of a slowly permeable clay of irregular contour. At Northfield the soil formation has particular difficulties for building. Both sites were studied and reports prepared for the authorities.

Preliminary studies of the characteristics of the heavy clay soils of the Wimmera are in progress, initially in the Horsham-Longeronong-Warracknabeal area. These will be similar in form to but less extensive than those for the Elizabeth project.

The engineering characteristics of the soils of the South Melbourne area have been studied, in an investigation to determine foundation requirements for the proposed King-street Bridge. This investigation, which is being undertaken for and in collaboration with the Country Roads Board, involves the sampling and testing to depths of 130 feet of soft alluvium and the underlying sand, gravels, and soft rock. A preliminary report has been prepared on the data from three sampling points.

(*d*) *Foundation Design for Domestic Buildings*.—An attempt has been made to define certain basic design procedures for the determination of appropriate foundations for domestic buildings. The purpose was originally twofold: (i) to make available to architects and engineers the results of past and current investigations on soil properties, and (ii) to define the range of soil properties requiring further research and investigation.

An important conclusion is that the behaviour of foundations of domestic buildings may be affected significantly by the consolidation of unsaturated clays as well as by the more obvious seasonal movements. Another is that it is not feasible to undertake investigations into soil characteristics affecting building stability without considering the characteristics of the superimposed structure (including the footings). The Division is collaborating in research of this nature with the Universities of Melbourne and Sydney through a subcommittee of the Institution of Engineers, Australia.

(*e*) *Engineering Characteristics of Unsaturated Soils*.—Studies of a fundamental nature have been undertaken as part of a long-term project to define the engineering characteristics of unsaturated soil as encountered in the Australian environment. Progress has been made so far on four phases of this work including—

- (i) the definition of the states and mechanisms of unsaturation and the measurement of conditions of unsaturation in zonal soils of the Australian environment;
- (ii) the study of the validity of the traditional effective stress concept of soil mechanics when extrapolated to the ranges of soil moisture tension and incomplete pore space saturation appropriate to the Australian environment;
- (iii) the study of the shear strength of unsaturated granular materials;
- (iv) the study of the shear strength of unsaturated clays.

(*f*) *Road Research*.—The Division collaborates with the State Highway Authorities and other organizations on soil problems associated with road construction.

An experimental programme has been planned to investigate the moisture status of subgrade soils (principally clays) throughout Australia. This work, which is still in its early stages, will be carried out in collaboration with the State Road Authorities. Two sites, one at Bordertown, South Australia, and one at Horsham, Victoria, have been selected and equipment has been installed. In the first place zonal soils in characteristic environments are being chosen to study the movement of water, by *in situ* techniques, under a pavement and under an adjacent vegetated area (carrying normal vegetation), and at all intermediate points. For installations in areas of low to moderate rainfall and high evaporation, the gypsum block moisture meter has proved suitable, and it is proposed to introduce the neutron moisture meter and tensiometers to cope with wetter sites. Close contact with the Soil Physics Section is being maintained in this work, which is still at an inconclusive stage.

III. PLANTS.

1. GENERAL.

Plants, whether in the form of crops or pastures, are the basis of every agricultural industry, and viewed in perspective grass is Australia's most important primary product. The Organization has placed considerable emphasis on investigations of plant problems at the Division of Plant Industry, which has its head-quarters in Canberra and is the Organization's oldest Division. The work of the Division, which has experimental farms and field stations throughout the Commonwealth, is described in this Chapter.

Allied work on mineral nutrition of plants carried out by the Division of Biochemistry and General Nutrition is described in Section 11 of this Chapter.

Work on special local problems of irrigation districts is undertaken by the Irrigation Research Stations at Merbein and Griffith (*see* Chapter IV.).

The Division of Entomology is carrying out work on weed control, insect pests of pastures and crops, and insect vectors of virus diseases (*see* Chapter IX.).

The Land Research and Regional Survey Section is carrying out broad-scale ecological surveys in the underdeveloped arid and semi-arid regions of the continent to assess their land-use potential and investigate problems of agricultural and pastoral development. The work of these regional surveys is reported in Chapter XI., Section 2, and the Section's investigations on crops, fertilizers, plant diseases, tillage, and native and introduced pastures under dry-land cultivation at the Katherine Research Station, and under irrigation at the Kimberley Research Station, are reported in Chapter XI., Section 3 *et seq.*

Research on biophysical aspects of plant growth is being undertaken at the Physics Department of the University of Tasmania and is reported in Section 22 of this Chapter.

Division of Plant Industry.—The research work of the Division is concentrated on problems which are fundamental to agricultural production in Australia. In this it is complementary to the activities of the State Departments of Agriculture, whose particular function it is to serve the more immediate needs of the agricultural industries.

Because of the importance of pastures in the Australian economy and also because of the difficulties of establishment, utilization, and maintenance of improved pastures, the Division has for many years been primarily concerned with these matters. Research in agronomy, agrostology, ecology, and plant nutrition has been pursued with the main aim of pasture improvement. Work in these fields is also directed to other crops of economic importance. Complementary to these studies, strong research teams have been established in genetics, microbiology, and biochemistry to undertake basic research on plants. It is believed that strong teams of scientific workers on fundamental problems will make possible in the long run a wealth of technological changes in the primary industries. The most recently established research team is that in the field of biochemistry and biophysics. This new unit will serve as a centre of plant biochemical research, and will be able to supply basic information for many current research programmes in the Division.

The main research projects of this group will be concerned with plant metabolism. Problems of animal production such as animal nutrition, poisonous plants, and fodder conservation will be aided by plant biochemical studies. One of the initial programmes of a more applied nature is a study of the pink pigment in root nodules which are actively fixing nitrogen. This pigment is very similar to the haemoglobin of animals, and it is possible that it plays a part in the mechanism of nitrogen fixation. Another such programme concerns the harmful by-products of pasture plants, such as the "oestrogenic" substances in subterranean clover, and the prussic acid-liberating substances in white clover.

More basic work includes studies of plant proteins and their synthesis by the plant, the way in which chlorophyll is formed in the plant, the mobilization of sulphur by soil bacteria, and the ways in which nutrients are moved from one part of the plant to another.

Plans for the establishment of a Tobacco Reseach Institute within the framework of the Division and financed from a Tobacco Research Fund have progressed favorably during the year. Professor D. W. Goodall of the University of Reading has been appointed as Director and will take up duties later this year. An agronomist and a plant breeder have also been appointed to work on problems directly associated with the industry. The Institute will be established at Mareeba in north Queensland.

A new concept in regional planning of research was instituted during the year with the formation of the Armidale Regional Research Committee comprising members of the C.S.I.R.O. Regional Laboratory, University of New England, and the Divisional head-quarters laboratories. The programme developed by this committee includes two major projects to be undertaken on the plant side; firstly, problems of pasture utilization in a region with a maximum summer rainfall, and, secondly, the study of the sulphur cycle in soils, and the effect of sulphur deficiency in plants and its effect on animal physiology.

Dr. R. D. Brock, of the Genetics Section, was awarded a Foreign Leader grant by the United States Department of State to enable him to study developments in radiation genetics. On his return from abroad he will concentrate on this aspect of genetics with the aim of producing wide variation in plant species as a means of obtaining suitable material for genetic improvement.

Mr. T. B. Paltridge, of Plant and Soils Laboratory, Brisbane, has been seconded to the Coconut Research Institute, Ceylon, under the auspices of the Colombo Plan. He will make a study of pasture establishment for native cattle under plantation conditions.

An overseas visit was undertaken by Mr. W. W. Bryan who visited Central America on a plant collecting expedition. In particular, he was seeking suitable legumes for pasture in northern Australia.

The Dickson Experiment Station, Canberra, was thrown open at a field day attended by some 200 graziers, and district agronomists of the Department of Agriculture. The experimental work demonstrated included pasture establishment and management, genetical work with subterranean clover, the field testing of plant introduction, and weed control.

The Division continued to provide specialized training to holders of F.A.O. Fellowships and of Fellowships under the Colombo Plan. The Division continued its co-operation with many State and Commonwealth Departments and universities and with overseas organizations. In particular, agronomists and plant nutrition officers have co-operated with the New South Wales Department of Agriculture at various field days in the Southern Tablelands area and have attended schools organized by the Department as guest lecturers.

2. PLANT INTRODUCTION.

(Division of Plant Industry.)

(*a*) *International Exchange.*—Although no active plant exploration has been conducted during the year, the number of samples of seed and other plant material received from abroad was larger than in the previous year. In total, some 5,400 samples were received from, or sent to, overseas countries, while large numbers were also distributed for trial within Australia.

All samples entering or leaving Australia are closely inspected, fumigated, cleaned, and treated in accordance with the quarantine regulations. The danger of bringing in virus diseases with vegetatively propagated introductions is especially serious, and has required special attention to such introductions as strawberry varieties, new varieties of couch grass, and the currently prominent forage plants, topine and Russian comfrey.

Apart from the quarterly introduction lists which are distributed regularly to Australian collaborators, a new seed exchange list has been prepared for overseas distribution. This list not only includes numerous varieties of pasture and crop plants grown in introduction nurseries in various parts of Australia, but also includes seeds of many indigenous plants recently collected in central, western, and northern Australia.

(*b*) *Agronomic Trials.*—Preliminary trials of specialized collections of important pasture grasses and legumes from the Mediterranean region have been conducted at Canberra, Perth, and Brisbane. Miscellaneous introductions of promise include the perennial *Secale montanum* from Turkey, and two strains of *Trifolium squarrosum* from Italy. The latter are very vigorous, leafy, erect legumes, which may be of value for hay or silage.

(i) *Canberra.*—Some 95 new introductions of *Phalaris tuberosa* have been established in a spaced-plant trial at Canberra, as well as smaller numbers of strains of other species of *Philaris* and *Lolium.* They have shown a greater range of maturity than the Australian commercial types and the better strains previously introduced. A late strain from Elvas, Portugal (C.P.I. 19344) and some strains from the Bône area of Algeria are agronomically promising. The introductions of *Phalaris truncata* were generally inferior to those of *P. tuberosa*, but some strains of *P. coerulescens* were highly productive and merit further trial in higher rainfall areas.

Pasture plants found promising in previous years have been further tested in swards and under grazing. In a comparative sward trial, *Bromus inermis* (C.P.I. 7073) has been outstandingly successful as an associate grass with *Phalaris*, and in mixtures with lucerne. This species also showed up well in continuously grazed blocks, and gave more even increases in sheep weight throughout the year and better carcass quality, than *Phalaris.*

(ii) *Perth.*—Relatively few new introductions, other than specialized collections, were established at the Kelmscott Plant Introduction Station, near Perth, but some of the earlier introductions continue to develop favourably. A strain of *Hyparrhenia hirta*, obtained originally from Holland, has persisted much better than *Phalaris* under frequent cutting, and has greatly outyielded it after the second year. Some introductions of veldt grass, from South Africa, are comparable with the local variety in yield but are more suitable for grazing. Recently introduced strains of purple vetch (*Vicia atropurpurea*) and common vetch (*Vicia sativa*) have considerably outyielded those previously available.

The successful commercialization of two early introductions of cocksfoot from the Mediterranean region—Currie and Neptune—has demonstrated the potentialities of this species in Western Australia, and extensive recent collections are being critically evaluated in a sward trial.

A detailed study has also been made of the collection of 172 strains of annual *Lolium*, while many species and strains of *Trifolium* have been established for comparative evaluation.

(iii) *Brisbane*.—The best of the collections of African and South American pasture grasses and legumes have been transferred from the old station at Strathpine to the new area at Samford. They have been established vegetatively in swards and subjected to periodic grazing which will be continued for some years. Marked differences in the reaction to grazing, both at the specific and varietal level, are already apparent and the trial will facilitate the selection of the best strains for regional trial and development. A similar series of grazing trials has also been established at Lawes, where species and strains of *Panicum*, *Paspalum*, and *Setaria* are outstanding among the grasses under trial.

A comprehensive varietal trial of soybean varieties at Lawes, including material from a wide latitudinal range, has confirmed the importance of photoperiodic and latitudinal comparability in work with this crop, and has indicated the value of many recent introductions. On the other hand, trials of *Phaseolus* species as grain legumes have suffered severely from insect pests and diseases.

(iv) *Regional Trials*.—Extensive regional trials have been conducted at many centres, especially in New South Wales and Western Australia. These are designed to assess more fully the regional adaptability of introductions found promising at the primary centres, and are frequently co-operative with Departments of Agriculture and other organizations.

In New South Wales, particular attention has been paid to *Phalaris tuberosa*, as the extensive collections of this species from the drier parts of the Mediterranean region offer the prospect of extending its cultivation beyond present limits. An interesting feature of a number of trials from south to north throughout the State is the general superiority of the later-maturing strains even in the inland centres, but this may not be maintained in a less favourable season.

In the northern parts of New South Wales, introductions of Rhodes grass, *Panicum coloratum*, and *Setaria* continue to be outstanding, and seed supplies are being built up as rapidly as possible with the co-operation of the Department of Agriculture and C.S.I.R.O. Regional Stations.

Work in Western Australia has included the continuance of regional trials at Kojonup and Wokalup, and the establishment of a new series of trials in drier areas at Nyabing, Lake Grace, Tammin, and Meckering. At Kojonup, work with cereals has been completed and seed of the better strains has been distributed to Departments of Agriculture. In studies of salt-tolerant plants, a species of *Puccinellia* from Turkey (C.P.I. 15034) is outstanding, and is being further investigated to determine tolerance limits. In the new series of trials at inland centres none of the grasses appeared to be superior to Wimmera ryegrass in productivity, but some of the annual *Trifolium* species are very promising, especially at the 14-in. rainfall sites.

(*c*) *Phalaris Growth and Dormancy Studies*.—Selected introductions of *Phalaris tuberosa* of known origin in the Mediterranean region are being critically examined under different environmental conditions in Australia. Preliminary experiments on a wider range of species have revealed evidence of the occurrence of ecological differentiation in five perennial Mediterranean grasses in response to various climatic factors. The present investigations are designed to study more fully the factors concerned and to relate them to the natural distribution of the plant in the Mediterranean region and its potential adaptability in Australia. At the same time, the effect of a new environment on a mixed plant population is being investigated by tracing the changes which occur in composite plots of mixed *Phalaris* strains at five different centres.

A clonal transplant experiment, utilizing selected strains of *Phalaris tuberosa* differing in morphology and physiology, has been established at Canberra, Condobolin, and Wagga. Detailed studies on an individual plant basis are being made at each centre.

In view of the significance of summer dormancy for the survival of perennial plants in a Mediterranean climate, investigations have been made of the factors determining the onset and breaking of dormancy in selected clones of *Phalaris tuberosa*. Preliminary glass-house experiments have shown the importance of temperature as a determining factor. Plants which would continue growth when supplied with adequate moisture at low temperatures would become dormant when the temperatures were raised, even though water supply was not limiting.

(*d*) *Plant Geography*.—A study has been made of the centres of distribution of the important cultivated pasture grasses in an attempt to define more clearly the potentialities of various parts of the world as sources of grasses for use in Australia. This has revealed the predominance of three main centres—Eurasia, east tropical Africa, and east central South America. The significance of the Mediterranean region as an important subsidiary centre has also been clearly demonstrated. This work will be extended to cover the important pasture legumes.

Environmental and botanical surveys of portions of the Mediterranean region and tropical America have been made to assist Australian scientists collecting in these regions.

3. GENETICS.

(Division of Plant Industry.)

(*a*) *Subterranean Clover*.—The research programmes aim at an understanding of the variation of and adaptive significance of characteristics of the species, their inheritance, and the incorporation of desirable attributes into new strains to extend the geographical or agronomic range.

(i) *Natural Selection*.—The aims of these studies, involving mixtures of strains and mixtures of hybrids, are (1) to estimate the value of hybridization, in self-fertilizing species, as a technique for releasing a larger amount of genetic variation than could be obtained from a mixture of the parents, as a means of increasing the chance of producing strains adapted to new environments; (2) to study the changes in both means and variances of morphological and physiological characters in the hybrid clover plots subjected to different environmental treatments, which study may elucidate the adaptive significance of some of the characters.

Plots have been established at 15 locations in New South Wales for these purposes. In addition, controlled differential irrigation treatments are being applied to plots of mixed hybrids and pure lines at Deniliquin.

(ii) *Subspeciation*.—Widespread genetic incompatibility within the species is indicated by pollen scores and seed-setting in a diversity of crosses. The Tallarook group (including Mount Barker, Bacchus Marsh, Burnerang, Mulwala, Cranmore, and Daliak) exhibits compatability with some lines and incompatability with others, from Morocco, Portugal, and Turkey. This suggests that subspeciation has occurred independently at different locations. Some sympatric strains are distinguished by differences of subspecific degree. Further crosses have been made between and within geographic regions.

(iii) *Flowering Time*.—Analysis of F_1, F_2, F_3, and parent material indicated that flowering time is determined by many genes and is strongly inherited. Physiological investigations of strain differences are being extended.

(iv) *Seed Dormancy.*—A survey of strains from the Mediterranean area disclosed wide variations. All strains germinate well at 10° C., but freshly harvested seed will not germinate at temperatures above a critical level which varies with strain. In general, seeds of strains from cold locations, especially if these are arid, require low temperatures. Collections from moist regions seem to be exceptional. The characteristic is inherited in a very complex manner.

(v) *Seed Yield.*—Progenies of F_2 plants selected for high or low seed yield have indicated heritability of the order of 0.35. Swards from certain high yielding plants excelled local commercial varieties with respect to dry matter production at the end of winter and seed yield per unit area.

(vi) *Sward Trials.*—Swards of 60 strains, including fifteen hybrid selections, are being established. The material includes a wide range of physiological and morphological types from the United Kingdom to the Canary Islands and Israel.

(*b*) *Other Legumes.* (i) *Lucerne.*—The transfer of the creeping habit into Australian lucerne from Siberian lucerne has been initiated. Several hybrid plants show desirable features. Combining ability of Australian and several introduced strains is being investigated.

(ii) *White Clover.*—Physiological and biochemical mechanisms underlying the cyanogenetic glucoside and leaf mark clines are being investigated.

(*c*) *Grasses.* (i) Danthonia.—Chromosome counts have been made on 28 species, and a study of breeding systems and isolating mechanism is in progress. Self-fertilization is usual but some natural crossing occurs. The existence of cytological or genetic isolating mechanisms is demonstrated by complete failure of many crosses and a high proportion of shrivelled seeds in others.

(ii) *Barley Grasses.*—Attempts to produce an awnless type of barley grass have been frustrated by sterility of crosses. An attempt is being made to obtain fertility by doubling chromosomes.

(iii) Themeda (*Kangaroo Grass*).—The distribution of chromosome races is being studied in a wide range of material.

(iv) Paspalum.—Cytological investigations have demonstrated that the species is apomictic. At meiosis twenty bivalents and ten univalents were consistently observed.

(v) Phalaris.—The genus consists of thirteen species, eight from the Mediterranean and five from America. Relationships between the species are being investigated. Clonally propagated plants of twenty introductions of *Phalaris tuberosa* are being studied at Canberra, Condobolin, and Wagga. Morphological and physiological studies on this and other material are to be used as a basis for plant breeding. Evidence for natural hybridization between *Phalaris truncata* and *P. brachystachys* has been found in recently introduced material.

(*d*) *Developmental Genetics.* Attention has been concentrated on inherited differences in plant growth. Differences between strains of *Arabidopsis thaliana* and mutants produced by radiation are being studied. Mutants have been found which require thiamin, sucrose, and a high osmotic pressure for growth. Varietal differences have been found for respiration rate (in subterranean clover) and in vitamin synthesis (in *A.thaliana*).

(*e*) *Mathematical Genetics.*—Research in this field is devoted to polysomic inheritance, linkage, and quantitative inheritance. The theory of trisomic inheritance has been developed. Tomato trisomic and disomic linkage studies will be made in a co-operative programme with Dr. C. M. Rick of the University of California. The theory of diallele crosses as applied to problems of quantitative inheritance has been developed.

(*f*) *Chromosomal Polymorphism in Grasshoppers.*—Work on *Moraba scurra* has established the existence of two heterotic mechanisms located on different chromosome pairs. Two races of this species differ in chromosome number, a large V-shaped chromosome in the eastern race having undergone " dissociation into two rods in the western race ". Study of the interracial hybrids has led to an understanding of the precise mechanism whereby the dissociation occurred.

In collaboration with Dr. K. H. L. Key (Division of Entomology) a cytological survey is being made of other grasshoppers of sub-family Morabinae. About 73 species have now been studied. Approximately twelve show chromosomal polymorphism. Most have an X_0 sex chromosome mechanism, but six have X_4 males and seven have an X_1X_2Y system. Also work has continued on a pair of sibling species of the genus *Austroicetes* which differ cytologically in several respects.

4. GENERAL BOTANY.

(Division of Plant Industry.)

(*a*) *Structural Botany.* Comparative studies in the morphology and evolution of monocotyledonous flowers have been continued. Material has been prepared for the examination of floral development from the families Graminae, Cyperaceae, Juncaceae, Juncaginaceae, Typhaceae, Alismataceae, Potamogetonaceae, Xanthorrhocaceae, and Liliaceae. The preparatory work has involved the collection, dissection, and mounting of sections for microscopic examination.

(*b*) *Toxonomy and Systematic Botany.*—Work has continued on the preparation of an Index to Australian Plant Genera. A card index has now been prepared covering over 4,000 names (including ferns). This covers synonyms as well as valid names, and both native and naturalized genera. Names important in agriculture have been included, but so far the coverage of horticultural plants is far from complete.

A complementary project has begun in the preparation of a card index to Australian species. In the absence of a modern flora of Australia full lists of species in any genus can only be obtained by reference to the Index Kewensis and its eleven supplements and to numerous papers. Even with this, the coverage may not be complete in the case of species described from specimens in other countries, but later found to occur also in Australia. Since this type of information is required as complementary to the index of generic names, as many as could be located have been copied from the Index Kewensis. When this copying is finished the search for species described elsewhere but occurring in Australia will be undertaken.

It is intended that as genera are revised the relevant card will be marked so that the correct name of a species can be seen at a glance, together with its various synonyms.

5. MICROBIOLOGY.

(Division of Plant Industry.)

(*a*) *Phytopathology.*—Research programmes in the field of plant disease are concerned with host-pathogen relationships, the effect of environment on disease development, and with various aspects of plant viruses.

(*i*) *Chemical Basis of Resistance in Plants to Fungal Attack.*—Further investigation of the mechanism of " active resistance " of plants to fungal diseases has led to the separation of an antibiotic principle in plant exudate from infected tissue; this principle arises as the result of interaction between living host tissue and parasite, where the former reacts in a suprasensitive manner. The antibiotic principle which appears in French bean pods after their infection with *Sclerotinia fructicola* appears to consist of two components which are dialysable. Crude preparations are active fungicides within a wide pH range, in the presence of nutrients, and after frozen storage for at least three months.

(ii) *Wound Healing and Reaction to* Phytophthora infestans.—Physiological changes initiated by the wounding of potato tubers have been found to involve an increase in the resistance of the cell layers adjacent to the cut surface prior to cutinization.

(iii) *Ripening Influence of Fruits Diseased by* Sclerotinia fructicola.—As the result of interaction between host and pathogen a gaseous principle is produced which causes, in adjacent healthy stone fruits, hastened pigmentation of the skin, premature softening of the tissues, and chlorophyll decomposition in the flesh without any increase in sugar content. The reaction is autocatalytic and after initiation proceeds in the absence of the pathogen.

(iv) *Brown Rot of Stone Fruits.*—Differences in incidence of brown rot in the Shepparton district noted under heavy waterlogging condition were again in evidence in a dry season when incidence on light soils was greater than that on heavy types.

(v) *Plant Virus Studies.*—Tobacco mosaic virus (T.M.V.) isolated from plants infected with a mixture of two T.M.V. strains has been resolved into two components by continuous flow filter-paper electrophoresis. These components correspond in biological properties to the two T.M.V. strains used in the inoculum. Milligram quantities of virus have been resolved in this manner. The same technique has been used in the separation of naturally occurring mixtures of plant viruses.

Investigations on the kinetics of T.M.V. lesion development on hypersensitive hosts have shown the rate of lesion growth to be a function of temperature and that the infectivity per lesion is a function of its size. Rate of development of lesions was found to be influenced by the physiological age of the leaf. The plant factor conferring hypersensitivity to T.M.V. could not be transferred by grafting.

Big bud of tomato and yellow dwarf of tobacco are being studied with respect to hormone and inhibitor concentrations in virus-diseased and healthy plants. Effects of photoperiod on long- and short-day tobacco plants infected with tobacco mosaic virus and of *Vinca rosea* infected with big bud are being examined in relation to sympton expression.

(*b*) *Soil Microbiology.*—Studies of host and bacterial aspects in effectiveness of nodulation, resistance to nodulation, and cytology and biochemistry of bacteroids have continued. Further work has been done on evaluation of nodule bacteria from Australian and overseas sources and on problems of faulty nodulation of subterranean clover in the field. The role of microorganisms in availability of soil nutrients has been studied further.

(i) *Symbiotic Variation in Subterranean Clover.*—Subterranean clover has been shown to be homogeneous in nitrogen fixing capacity, and selection within varieties or in hybrid material has not given significant results. Most strains of bacteria, whether effective or ineffective, produce the same amount of nodular tissue. Occasional strains vary in this regard and there is some evidence that such divergencies in nodule pattern may be simply inherited.

(ii) *Symbiotic Variation in Red Clover.*—Ineffectiveness due to a recessive gene has been shown to be associated with the proliferation of the infected host cells. Another gene is concerned with failure in bacteroid formation. Anatomical and cytological features associated with the operation of these genes have been studied.

(iii) *Physiology of Infection.*—Infection takes place at discrete foci on the root; these are available for infection over a limited period and the probability of infection at a single focus remains approximately constant. If the dilution of the infecting agent is so high that certain foci are not occupied, they may give rise to further foci.

(iv) *Anatomical Studies of Root Nodules.*—It has been found in *Trifolium ambiguum* that failure to fix nitrogen, whether due to host variation or the use of unsuitable strains of bacteria, was characterized by the persistence of an immature type of bacteroid-containing tissue in which the cells accumulated large amounts of water-soluble polysaccharide between protoplast and cell wall. This polysaccharide was found to be a hitherto undescribed feature of all Trifolieae nodules, but occurs only in the regions where bacteroids are being formed. Delayed inoculation and late nodulation of clover and medics have been found to accelerate the rate of decay of bacteroid-containing tissue. A type of ineffective nodulation has been observed in subterranean clover in which bacteria were not released from infection threads but multiplied within them.

(v) *Studies on Bacteroids.*—Cytological studies and cytochemical tests have shown that metabolism of Krebs cycle intermediates such as succinate and pyruvate was confined to the peripheral mitochondria-like granules, while oxidation of glutamate and aspartate occurred throughout the cytoplasm. Suspensions of bacteroids from subterranean clover nodules are being used in biochemical investigations concerning the essential functional differences between bacteroids and the rod forms of *Rhizobium* from which they arise. Respiration studies show differences in glutamate and succinate metabolism, and bacteroids are more sensitive to lowered osmotic pressure than rod forms.

(vi) *Bacterial Strain Variation.*—Investigations of the relative effectiveness of nodule bacteria occurring on subterranean clover in the field in relation to seed inoculation and fertilizer applications have been initiated.

(vii) *Host Resistance.*—Resistance to nodulation in a line of soybeans, owing to a gene mutation at a single locus, in incapable of modification by grafting; such plants are resistant to all strains of bacteria. On the other hand, in *Trifolium abiguum,* resistant plants exhibit very delayed susceptibility to infection, possibly combined with a sparse infectibility; in this case the strain of bacteria is important in terms of the degree of resistance.

(viii) *Delayed Inoculation.*—With subterranean clover a delay of two or three weeks signicantly shortens the time from inoculation to nodule development, but beyond this nodulation is delayed initially. For some weeks, at least, the nodules finally produced are less effective than those on plants where no delay or only a short delay has occurred.

(ix) *Effective Field Establishment of Subterranean Clover.*—The problem of faulty nodulation of subterranean clover on granite soils of the New England region was defined as the inability of known strains of *Rhizobium trifolii* to multiply in the rhizosphere of the seedling. Failure of seed inoculation, due to microbiological antagonism in the rhizosphere, was reduced by prior cultivation and by the presence of charcoal. Very heavy rates of inoculation were effective in the year of clover establishment.

(x) *Phosphate Transformations during Decomposition of Organic Matter.*—The solubility of rock phosphate was greatly increased by mixed cultures in liquid medium in the presence of organic matter which decomposed to form acid, but this effect was not apparent in soil. The phosphate in ferric phosphate became soluble in liquid media under both acid and alkaline conditions, although with some organic sources the phosphate did not remain in solution for extended periods. Similar increases in soluble phosphate were detected in soil which reecived ferric phosphate and was incubated under anaerobic conditions with sugar.

(xi) *Microbiological Oxidation of Manganous Salts.*—When added to soil manganous salts are oxidized by microorganisms. The oxide so formed was prepared in pure bacterial cultures and was found to be an amorphous hydrated manganese oxide. In this form the manganese was completely available to plants grown in sand culture, but was only slightly available when added to a soil deficient in manganese.

6. FRUIT INVESTIGATIONS.

(Division of Plant Industry.)

(*a*) *At Hobart.*—(i) *Physiology of Apple Fruits in Relation to Storage Disorders.*—Experiments have been directed firstly to study of the basic responses to nitrogen when applied as a urea spray, and secondly to examine the possibilities of varying those natural growth substances which are of fundamental importance in controlling the size, structure, and keeping quality of the fruit.

The work has shown that applications of nitrogen in the form of urea presents difficulties; in dry seasons spring applications are ineffective and may produce leaf scorch, and summer applications may reduce fruit colour. Nitrogen, introduced by urea sprays, accumulates as protein and soluble nitrogen, the latter increasing faster. These increases have no effect on respiration rate at picking. The influence of nitrogen on disorders operates mainly through its effect on size, the direct effect being very small. In fact, the bad effects of high nitrogen may be less serious than nitrogen starvation which finally depresses both yield and keeping quality.

Leaf sprays of phosphorus and potassium have had no effect on the fruit content even after three seasons.

The responses to growth substance treatment were reduced by drought, but even so it appears that the seeds and the growth substances associated with them are important in fruit growth and keeping quality. It was found that seed number has no relation to keeping quality.

(ii) *Gas Storage.*—A survey of a wide range of varieties has shown that low oxygen concentrations in the absence of carbon dioxide have allowed the use of low storage temperatures without increasing the susceptibility to low-temperature breakdown. These conditions have given good control of softening, have reduced wastage from disorders and rots, and have markedly reduced the proportion of soluble pectin. The texture of fruit is also superior under these conditions of storage. A pilot-scale trial of the method has been successful.

The first commercial gas store in Tasmania has been constructed with C.S.I.R.O. advice and commenced operation in the 1956 season.

(iii) *Diphenylamine Treatment for Apple Scald.*—In 1955 Cornell University released advance information to the Laboratory at Hobart on the possibilities of this substance for the control of apple scald. This advanced by twelve months the research on this important disorder. The experiments instituted here have shown that diphenylamine exerts a greater control of this disorder than any existing treatment and can be combined successfully in the first wrap. Even if this substance finally proves to have limitations the discovery of its effect has opened a new avenue of research.

(*b*) *At Applethorpe, Queensland.*—(i) *Apple Rootstock Trials.*—The necessity for considering fruitfulness of stock-scion combinations and not vigour of growth alone is exemplified by the cropping records of Jonathan and Granny Smith on Malling XII. and Spy rootstocks. With Jonathan trees eighteen years old, M.XII. stock has produced the largest trees and the largest total crop of 1530 lb. per tree; Spy has produced only 1110 lb. per tree. On the other hand, Granny Smith trees on M.XII. although still the largest trees have produced 1360 lb. of fruit per tree, whereas the much smaller trees on Spy produced 1435 lb.

In the pruning and stock trial the trends developed in cropping in early years still persists at seventeen years, with the Wickens trained trees still maintaining the lead, in weight of fruit borne, over the more severely pruned trees.

(ii) *Pear Rootstock Trials.*—Some vegetatively propagated pear stocks which were selected for their ease of rooting by layering methods were budded to Williams pear five years ago. Greater vigour of growth is shown with trees on selections 1, 7, and 8 than by those on the commonly used Kieffer seedling stocks.

(iii) *Storage Quality of Fruit.*—This is the first full year of operation of the new storage cabinets at the Field Station. Jonathan and Granny Smith fruits are being stored from a range of rootstocks and fertilizer treatments. Data for a study of the effect of climate and orchard factors as well as variation in the cell number of fruits are being accumulated.

7. OIL CROPS.

(Division of Plant Industry.)

(*a*) *Safflower* (Carthamus tinctorius *L.*).—Safflower trials carried out through the co-operation of the State Departments of Agriculture have defined areas in Australia where safflower can be satisfactorily grown. In general, areas with a mean annual rainfall of less than 20 inches are too dry for safflower to yield satisfactorily. The drier wheat belt areas of Australia are therefore unlikely to be suited to this crop. Under southern Australian conditions in the higher rainfall areas, poor emergence due to cold wet conditions at sowing time, and susceptibility to weed competition due to slow growth during the cold winter months, often result in safflower failure and make it a risky crop.

Promising results in terms of yield have been obtained in the north-west of New South Wales and the Darling Downs, Queensland, where difficulties of establishment are not a problem. In these areas safflower has at least equalled, and in most cases exceeded, linseed in the yield of oil, and in most cases exceeded wheat in monetary return. Satisfactory results have also been obtained in more northern areas of Australia.

Trials are being carried out to determine the most satisfactory varieties for oil yield and quality in the promising areas. The varieties being tested are selections from material introduced from overseas.

Agronomic trials have been continued. Close spacing (7-in. rows) of safflower resulted in a greater yield of seed per acre and higher oil content than wider spacing (21 and 28 in.).

(*b*) *Linseed.*—Studies were continued with a number of introductions and selections from a cross of Punjab × Walsh. A number of these were considerably superior in yield to the varieties Walsh and Punjab and were not affected by rust under field conditions.

8. TOBACCO INVESTIGATIONS.

(Division of Plant Industry.)

(*a*) *Genetics and Agronomic Studies.*—(i) *Breeding.*—A hundred local races of *Nicotiana* species (including the Australian species and naturalized strains of *N. tabacum* and *N. glauca*) have been grown in the greenhouse and tested for resistance to blue mould, tobacco mosaic, and frenching. All were susceptible to mosaic and to frenching. All samples of *N. glauca* and *N. tabacum* were susceptible to blue mould, although a few plants of one strain of *N. tabacum* (T.S.17 received from Modlow, Queensland) escaped infection. The races of the Australian species varied from complete susceptibility to almost complete immunity to blue mould.

The breeding programme for blue mould resistance in commercial flue-cured tobacco was expanded during the year. *N. goodspeedii* crosses have been the most resistant of those tried, but there appears to be a falling off in resistance with each backcross generation, the second being, on average, less resistant than the first. The second backcross generation was made continuing with the *N. goodspeedii* cytoplasm by using the first backcross as the ovule parent; the progeny are developing male sterility of the type described by Clayton for his *N. debneyi* and *N. megalisophon* crosses. Commercial flue-cured *tabacum* varieties were used as ovule parents and the backcross as the pollen parent, very few viable seeds were obtained, and most of the plants from them are dying before reaching the flowering state. Other varieties of *N. tabacum* are now being tried as the ovule parent.

Two lines of tobacco with *N. debneyi* parentage were received from the United States Department of Agriculture during the year. One contains a proportion of *debneyi*-like plants resistant to blue mould, the other is readily infected by blue mould, which causes severe leaf distortion, but only slight spore production on some of the plants. These two lines are being further backcrossed to *N. tabacum.*

Radiation treatments of pollen and of dormant seeds of *N. tabacum* have failed to produce any mutation conferring even a slight degree of resistance in any of the several thousand plants that have been tested in the first generation following the irradiation. This work is being continued, and the possibility of recessive mutations conferring resistance will be tested in the next generation of selfed plants.

(ii) *Diseases and Disorders.*—In field-grown tobacco plants side-dressed with inorganic nitrogen, blue mould spread throughout all leaves, whereas it was not severe in plants grown on soil high in organic manure. In plants low in nitrogen such as are grown for flue-curing, the most rapid spread of diseases occurred in leaves growing rapidly and nearing full size. Leaf damage was determined by the stage of leaf development and not by number of established infections.

In seedings, efficiency of benzol vapour in preventing infection and spread of the fungus within leaves is affected adversely by the presence of excess moisture on leaves, or within the seedbed, during the day. The fungus causing blue mould was established in wet leaves and continued to develop slowly even though the quantity of benzol used prevented its development in dry seedlings. Neither " Zineb ", which is recommended for control of blue mould in the United States, nor the antibiotic streptomycin, gave satisfactory control of the disease in seedlings. From this and from other evidence on host-plant relationships it appears that different strains of the fungus causing blue mould may occur in the United States and Australia.

Separation of soil extracts (filtrates) into fractions by filtering, flocculation, and centrifuging was used in the study of frenching of tobacco. The frenching ability of the fractions was determined by suspending healthy tobacco seedlings in Erlenmeyer flasks with their roots immersed in a solution of each fraction. Some soils were equally effective in causing frenching but their filtrates behaved differently. Fine filters retained all, or almost all, of the frenching factor. The ability of a filtrate to cause frenching was destroyed by boiling for a few minutes.

A blue mould survey was undertaken in the Ovens River Valley, Victoria, where tobacco fields were inspected at three-weekly intervals throughout the growing season to observe the destructiveness of blue mould, and more especially, differences between and within fields.

(*b*) *Tobacco Quality.*—Investigations were continued at the Waite Agricultural Research Institute, Adelaide, special attention being given to carbohydrate and amino acid content of leaves as determined by paper chromatography methods. It was considered that the low carbohydrate and amino acid content found in trashy leaf may have been a consequence of conditions during growth or of losses during respiration in the early stages of flue-curing. These possibilities were examined in a study of the effects of nitrogen-potash nutrition on leaf quality. It has been found that the best-quality flue-cured leaf was obtained from plants supplied with high nitrogen and high potassium. The poorest leaf was produced where potash supply in relation to nitrogen was low. A range of degrees of trashiness was shown by plants with intermediate potassium to nitrogen ratios.

9. General Chemistry.

(Division of Plant Industry.)

(*a*) *Phosphorus Availability.*—Only a small proportion of the total phosphorus in soils is in forms available to plants. Generally about one-third to one-half of the total phosphorus is in organic forms, which, although unavailable to plants, could become available if mineralized to inorganic forms. Very little is known of the exact nature of these organic phosphorus compounds in Australian soils, and work has been commenced to attempt the isolation and identification of the major compounds. Initially, work is being directed towards the separation, identification, and estimation of inositol phosphate and phytic acid derivatives.

(*b*) *Sulphur Availability.*—Total sulphur has been determined in 125 surface soils from eastern Australia. These analyses have shown that the soil sulphur is closely related to both soil carbon and nitrogen which indicates that the greater proportion of the soil sulphur is probably an integral part of the soil organic matter. Acid soils had a carbon : sulphur ratio of 120 while alkaline soils had a ratio of 83. This difference between acid and alkaline soils appears due to a difference in the nature of the organic sulphur compounds rather than to the presence of larger quantities of free sulphate in the alkaline soils.

(*c*) *Trace Element Availability.*—(i) *Manganese.*—Studies on a manganese deficient soil from Rendelshaw, South Australia, have shown that small additions of manganese have produced decreases in the concentration of manganese in the plant. Larger additions of manganese, however, produced an increased concentration of this element in the plant. These results, apart from their fundamental interest, indicate difficulties in the diagnosis of manganese deficiency from simple plant analyses.

(ii) *Molybdenum.*—Investigations of the absorption of molybdenum by soils indicate that in acidic ferruginous soils molybdenum is held on the surface of colloidal ferric oxide as the molybdate anion which is replaceable by hydroxyl ions.

(*d*) *Soil Fertility Studies.*—A survey of the influence of superphosphate and subterranean clover on soils in the Crookwell district of New South Wales indicated that the soil pH decreased under the clover pasture. Soils which had a pH of about 6.1 decreased in pH to values as low as 5.1 over a period of 26 years.

Laboratory investigations have shown that this fall in pH results indirectly from an increase in the organic matter under the improved pasture which leads to an increase in the cation-exchange capacity of the soil from about 5 milli-equivalents per 100 g of soils to about 10 milli-equivalents over a period of 26 years. In the absence of any appreciable input of metal ions this has led to an increase in exchangeable hydrogen, with consequent fall in pH.

These investigations have also shown small, but significant, increases in the exchangeable calcium, magnesium, and potassium in the surface under improved pasture. These increases apparently result from deeper root penetration of the improved pasture enabling these nutrients to be brought from sub-surface depths to the surface.

(*e*) *Cobalt Uptake by* Phalaris.—Plant material has been grown and spectrochemical analyses are in progress to study differences in cobalt content and cobalt uptake between ecotypes of *Phalaris.*

(*f*) *Nutrition of* Pinus radiata.—An experiment in collaboration with the Forestry and Timber Bureau has been commenced, to study the uptake of boron, copper, magnesium, molybdenum, nickel, and zinc by ines following the addition of these elements to the soil. Spectrochemical analysis on samples from this experiment are in progress.

(*g*) *Frenching of Tobacco.*—Symptoms of lead toxicity in tobacco have been observed to resemble early symtoms of frenching. Lead is of widespread occurrence in soils, and conditions known to favour frenching are those favouring an increase in the solubility of lead. Spectrochemical and glass-house experiments have provided evidence which suggests that lead may be a contributory factor in the frenching of tobacco.

10. PLANT NUTRITION.

(Division of Plant Industry.)

(*a*) *Lime-pelleted Clover Seed.*—Promising results have been obtained by pelleting clover seed with lime. The lime pellet protects the *Rhizobium* inoculum from soil acidity and so allows nodulation of clover plants on soils which are otherwise too acid for the survival of *Rhizobium.*

Early research on a moderately acid soil deficient in molybdenum showed that the failure of the clover was due to the lack of molybdenum for symbiotic nitrogen fixation. On the other hand, the failure of lucerne on the same soil was due to the lack of nodules on the lucerne plants as well as to deficiency of molybdenum for symbiotic nitrogen fixation. Heavy dressings of lime allowed nodulation of the plants, and also corrected the deficiency of molybdenum by increasing availability in the soil. Thus the lime had a dual effect on the lucerne.

On more acid soils lime had a dual effect on subterranean clover by allowing nodulation and increasing the molybdenum supply. In experiments on the Southern Tablelands of New South Wales it was shown that the amount of lime needed to allow nodulation of the subterranean clover was very much less than the amount needed to correct the molybdenum deficiency. It therefore became possible to develop this country more economically by using molybdenum superphosphate to correct the molybdenum deficiency, and by drilling inoculated clover seed with only 2 cwt. of lime per acre to allow nodulation. Further research showed that where superphosphate had been applied, the lime counteracted the acidity of the soil in the immediate environment of the seed, and that numbers of rhizobia in the soil increased. This showed that the calcium in the lime was not required as a fertilizer, and hence opened up the possibility of creating a favorable microenvironment for the *Rhizobium* inoculum by coating the seed with lime.

(*b*) *Ammoniated Superphosphate.*—Several other methods were tested to determine the best means of overcoming the problem of defective nodulation of legumes on acid soils. Recent work has shown that superphosphates will absorb ammonia in sufficient quantities to counteract the harmful effects of both superphosphate and soil acidity on the *Rhizobium.* Ammoniated superphosphate used commercially as a combined N-P fertilizer in the United States supplies nitrogen to the young plants and has a very marked beneficial effect on the nodulation of clover on acid soils.

(*c*) *Supply and Availability of Elements.*—An experiment at Canberra to determine the effect of subterranean clover on the nitrogen status of the soil is being continued. The effect on the yield of a cereal crop will be measured.

(*d*) *Factors Affecting the Response to Fertilizers.*—Experiments to determine the residual effects of fertilizers are being maintained. These include experiments with superphosphate, rock phosphate, sulphur, molybdenum, and boron. Residual effects of molybdenum have now been observed for ten years. There is still a marked response to a dressing of 2 oz. of molybdenum trioxide per acre applied only in the year of sowing (1946). A dressing of molybdenum in 1955 gave a marked response on plots where molybdenum had not previously been used, but no response on plots where the original dressing had been applied in 1946.

(*e*) *Role of Elements in Plants.*—Research on sulphur and nitrogen metabolism in plants is being continued.

The work on purification of the plant enzyme carbonic anhydrase has shown it to be very unstable. The enzyme carbonic anhydrase in animals contains zinc, but there is no evidence that the plant enzyme does.

Preliminary tests were made to examine the possible effect of potassium deficiency on any salt respiration that may accompany the uptake of potassium. Although potassium deficiency influenced the rate of uptake of potassium, there was no concomitant effect on the salt respiration.

11. MINERAL NUTRITION OF PLANTS.

(Division of Biochemistry and General Nutrition.)

The experiments mentioned in previous Reports have been continued to examine in greater detail the distribution of zinc and copper in plants. *Trifolium subterraneum* var. Bacchus Marsh was again used as the test plant. Three lines of investigation were followed, viz.:—(*a*) a re-examination of the distribution of zinc at different stages of growth, (*b*) an examination of the changes which takes place in the distribution of zinc and copper during short periods of time, and (*c*) an examination of the distribution of zinc under different conditions of zinc supply.

(*a*) Plants were grown in culture solutions in which the zinc was tagged with the radioactive isotope ^{65}Zn. The distribution of zinc in the various organs at different stages of growth was examined by means of radioautographs. The distribution of ^{65}Zn within entire and dissected inflorescences and in developing and mature seeds was examined in detail by the same technique.

(*b*) Seedlings grown in complete culture-solution and in zinc-free cultures were examined after short intervals of time during the first 46 days after germination. At each harvest the leaves were separated from the petioles and grouped according to age. In this way it was possible to follow closely the gains and losses in dry weight and in zinc and copper content of successive, healthy leaves as they emerged and expanded, and to observe how leaves of comparable age behaved during the gradual onset of zinc deficiency.

(*c*) Changes which take place in the distribution of zinc during the onset of zinc deficiency, on the one hand, and during recovery from a state of acute zinc deficiency, on the other, were determined by means of radioautographs prepared from young plants grown in culture solutions to which appropriate additions had been made of either inactive zinc or zinc tagged with ^{65}Zn. By similar means it was possible to observe the extent to which zinc absorbed by the plant during early growth becomes redistributed, and to determine the location of recently acquired zinc.

The results add detail to the knowledge of the location and movement of zinc and copper in plant tissues and indicate the trend of the changes in amount and concentration of zinc and copper that take place in individual leaves. A series of publications is being prepared.

12. PLANT TOXICOLOGY.

(Division of Plant Industry.)

(*a*) *Herbicide Tests.*—Additional poisons prepared by the New South Wales University of Technology have been tested. Phosphonous acid analogues of 2,4-D have little toxicity, and in some instances behave as antiauxins. The glycine analogue of 2,4-D is as active as a poison and an auxin as is 2,4-D itself.

(*b*) *Mistletoe Investigations.*—Field tests have been continued in collaboration with the Forestry and Timber Bureau on the killing of eucalypt mistletoe. For the first time more effective treatments than 2,4-D have been found, viz. 2,4-D plus borax, 2,4-D plus 2,4,6-T, and 2,4-D acid hydrazide. Further tests with these compounds are being made at higher concentrations, and in addition, tests are in progress with phenoxybutyric acid derivatives.

(*c*) *2,4-D Extraction.*—A method has been evolved for extracting 2,4-D from mistletoe and eucalypt leaves. Conventional methods were unsatisfactory owing to interference caused by the essential oils in eucalypt leaves.

(*d*) *Impedance Studies.*—These have been applied to the measurement of injury caused by auxins and poisons, and for the development of a test for both auxin and toxic activity.

It has been found desirable to use a correction for length of section when making either low-frequency resistance probe readings (R_{LF}) or high-frequency resistance probe readings (R_{HF}) alone. Thus after a possible intitial increase (depending on the poison) R_{LF} x length decreases with increasing injury, whereas R_{HF} $\div$ length increases with increasing injury. This is because at low frequencies the main resistance in living tissues occurs at cell junctions, while at high frequencies resistance depends essentially on electrolyte concentration. However, it is considered that R_{LF}/R_{HF} gives a better index of injury for many purposes, approaching the value 1 when death occurs.

(*e*) *Translocation Investigations.*—Results obtained with orthoarsenic acid applied to skeleton-weed are not in accordance with accepted theories of translocation which claim that the applied poison moves with the photosynthate stream. Even if the leaves are sprayed with the arsenic acid after four days in darkness, good kills of the root are obtained.

(*f*) *Root Cultures.*—For toxicity studies a method of liquid culture has been devised for skeleton-weed root sections. Best results have been obtained with a solution containing 9 per cent. mannitol and 0.01 per cent. salt solution. Sections remain healthy for more than a fortnight and accumulate little salt.

13. PLANT PHYSIOLOGY.

(Division of Plant Industry.)

(*a*) *Hormone Physiology.*—(i) *Hormone Transport.*—Attempts to induce acropetal movement of auxin through segments of *Phaseolus* hypocotyls were unsuccessful except when treatment killed the tissue and allowed the possibility of simple diffusion.

Information relevant to the problem of polar transport has been obtained by studying the transport of indoleacetic acid (IAA) through segments of bean hypocotyls previously treated with a range of synthetic growth regulators. Many such substances, including 2,4-D, inhibited IAA transport, and the results are compatible with a hypothesis that they compete with IAA for " carrier sites ". In addition to their action on plant cells locally, commercial growth regulators which behave similarly to 2,4-D must also influence plants by interfering with auxin distribution.

(ii) *Frenching of Tobacco.*—Large-scale quantitative estimations of the growth substances in leaves and stems of normal and frenched plants from a commercial crop in Western Australia have confirmed the preliminary finding reported last year—that the development of frenching symptoms in tobacco is accompanied by a reduction in the extractable amount of the chief natural hormone, IAA. However, this auxin deficiency is now not considered the central mechanism responsible for the appearance of symptoms. It is rather a reflection of reduced activity of the stem apex, and it is the latter that leads to aberrant leaf development.

The concept of the activity of the stem apex having a controlling influence on the development of symptoms can be extended to other cases where the interfering factor may be a virus or mineral deficiency. The virus disease, big bud of tomatoes, is under investigation, using the same techniques as before.

(*b*) *Plant Development.*—(i) *Flower Initiation.*—Two experiments with *Anagallis arvensis* L. were carried out to establish stages in flower primordium initiation, and rates of development of such primordia in relation to the intensity of the evoking environmental stimuli (here chiefly length of day). The experience gained will enable similar investigations to be undertaken on plants of agronomic importance, such as subterranean clover.

(*c*) *Seed Physiology.*—(i) *Dormancy in Subterranean Clover.*—Further evidence on the action of carbon dioxide and activated carbon in breaking dormancy has been obtained. A concentration of carbon dioxide as low as 0.3 per cent. is effective under certain conditions. The relative efficiency of these treatments has been established for a range of varieties of different geographic origin, and at different stages in progress out of dormancy. In a similar fashion, complex experiments involving transfer of material between low and higher temperatures (the intensity and duration of cold being varied) have given information on the favorable action of low temperature in breaking dormancy.

Of these three treatments, carbon dioxide was always the most effective dormancy breaker. The results support the view that the germination process consists of a series of interlinked reversible reactions. Low temperatures, activated carbon, and carbon dioxide all operate by controlling the effective carbon dioxide concentration at some internal site, and making possible an early reaction step.

Such concepts are of value in characterizing strains and varieties for agronomic purposes.

(ii) *Germination Inhibitor.*—A simple bioassay has been established for the detection and semi-quantitative estimation of the germination inhibitor present in *Echium plantagineum* L. The inhibitor has been found, not only in the seed, but throughout the plant. Progress has been made in the concentration and purification of the inhibitor from crude extracts.

(*d*) *General.*—(i) *Nitrogen Metabolism.*—Using plant embryos it was established that, of the optical isomers of asparagine, only the L-form stimulated growth. The substance α-oximino-glutamate, a hypothetical intermediate of plant nitrogen metabolism, inhibited growth at concentrations at which glutamate stimulated.

(ii) *Pollen Germination.*—In plant breeding, the impossibility of obtaining certain desirable crosses may be concerned with pollen-stigma and style relationships. For this reason, a study of the *in vitro* germination of pollen has been initiated. Glutamine strikingly stimulates pollen germination and pollen tube growth in *Medicago sativa.*

(iii) *Soil Fertility.*—Soil fertility can be defined in terms of crop responses rather than by the physical and chemical properties of a soil. This approach has been used in an investigation of the effects on crop growth of adding large quantities of organic matter to the soil. Declining soil fertility in terms of crop response is a high priority problem wherever semi-arid soils are irrigated. The Murrumbidgee Irrigation Area is no exception to this, and there are many advocates of organic farming as a solution of the problem. For this and other reasons it was decided to seek an understanding of the effect of incorporating large quantities of strawy material into the soil. Most of the work has been done with rice hulls, but field trials were also made with other materials.

The main finding of the early work was that growth was stimulated by a marked increase in the availability of soil phosphate. Further work has been concentrated on this phosphate effect, and a series of pot experiments has shown beyond reasonable doubt that the extra phosphate was released from the "frozen assets" class of soil phosphate, and did not come from the rice hulls hemselves.

14. Plant Ecology.

(Division of Plant Industry.)

(*a*) *Studies on Native Grasslands.*—(i) *Autecological Studies of* Bothriochloa ambigua.—A study of certain soil characters in relation to the invasion of native pastures by *B. ambigua* has been completed. The experimental establishment of *B. ambigua* in native pastures has again been impeded by unfavorable climatic conditions.

(ii) *Autecological Studies of Native Species* (*Trangie, New South Wales*).—The economy of the Trangie district s based largely on grazing of native annual and perennial species. The basic aims of present studies are to establish the yearly microclimatic cycles, the area over which they apply, and the response of the major native species measured in phenological terms to the microclimatic environment. A rich ground flora has been maintained over the past year of unusually high rainfall. Since February, 1955, soil moisture has fluctuated but has never been limiting. The relative effectiveness of rainfall on the two soil types in the area has been studied.

(*b*) *Alpine Ecology.*—An alpine ecologist was recently appointed and is now located at Island Bend in the Snowy Mountains. The prime objective of this appointment was that ecological studies should be undertaken in alpine and subalpine areas of south-eastern Australia, particularly the relationships of vegetation to the conservation of water. The initial projects have included a reconnaissance ecological survey of the Australian Alps, a reconnaissance ecological survey of the Victorian section of the Alps, and a study of current soil and vegetation trends. The study of soil and vegetation trends is still in progress, and field work in respect of the ecological and glaciological surveys has been completed.

The study of soil and vegetation trends in high mountain catchments was commenced as an essential step towards rehabilitation. It is now generally agreed that these areas have been damaged and whether they are improving or deteriorating further is a contentious issue. The present study is showing that badly damaged areas are continuing to deteriorate, whilst favorably suitated areas are generally improving. A more significant finding, however, is that marked changes have occurred in the overall hydrology, in the direction of more rapid run-off, less infiltration, and increasingly erratic stream flow. It is these changes which present some of the main problems in successful catchment management.

The conclusions drawn from this and earlier work are hat satisfactory catchment conditions can be ensured only by readjusting land use, combined in more seriously damaged areas with active conservation works. The readjustment of land use considered necessary would require complete prevention of fires, and exclusion of livestock rom virtually all areas above 4,500-4,750 feet. In the emaining high mountain areas below this limit, successful management as a catchment-grazing resource might be possible, provided current grazing practices were changed. The manner in which grazing would have to be conducted s a study planned for a later date.

(*c*) *Ecology of Subalpine Grasslands.*—Studies of the rigin of treeless grasslands in the subalpine areas of New outh Wales have continued. Nocturnal temperature profiles in elevated valleys have been determined and transplant experiments along transects have commenced. The olerance of tree-line eucalypts to low temperatures is being tudied in the laboratory.

(*d*) *Rain-forest Ecology.*—The preliminary phase of general survey and classification of Australian rainforests has been completed. Seven papers have been prepared for publication dealing with the environmental relations of different subforms of local vine forests.

Microclimatic and hydrological studies at Whian Whian State Forest near Lismore, New South Wales, are continuing in collaboration with the C.S.I.R.O. Division of Soils and New South Wales Forestry Commission.

Factors limiting germination, establishment, and growth of certain rain-forest species are being studied.

(*e*) *Vegetation Survey of Part of Macquarie Region, New South Wales.*—The area is roughly 4,800 square miles and is bounded approximately by Trangie, Mendooran, Gulargambone, and Dubbo. It covers the changes from the flat country in the west to undulating and hilly country in the east. The vegetation has been classified in ten alliances (the mapping unit), each with one or two associations. Eight alliances are dominated by *Eucalyptus* spp., one by *Acacia pendula*, and one is a *Stipa* grassland.

Field observation indicates multiple-factor control of the distribution of the communities. The principal factor is soil type, functioning mainly through texture, moisture, and nutritional status. Climatic limitations *per se*, in the form of seasonal incidence of rainfall, is apparent in one or two instances only.

Present land use of the alliances and the effect of clearing, grazing, or cultivation on the vegetation (particularly the pastures) have been defined.

(*f*) *Ecological Studies on Weeds.* (i) *Competition between Skeleton-weed* (Chondrilla juncea *L.*) and *Cereal Crops.*—Three preliminary trials have shown nitrogen to be the main factor in the competition between skeleton-weed and cereal crops. Under conditions of moderate to low fertility competition was very severe. The depressing effect of the weed on cereal yields can be removed by applying high rates of fertilizer nitrogen or by planting where fertility has been built up by subterranean clover. Last season the temporary removal of the competition by spraying at various times was used to find the growth stage when competition for nitrogen was critical. It was found that the usual commercial spray is applied long after the weed has exerted its effects. Early spraying gave higher yields owing to removal of skeleton-weed early in the crop's growth when nitrogen supply was critical.

(ii) *Competition between Pastures and Skeleton-weed.*—At Canberra the reduction of skeleton-weed populations by different species of pasture plants and by fertilizer treatment has been determined. Sown species have reduced weed populations after five seasons but complete control is unlikely. The reduction of populations is partly due to competition from volunteer grasses which invade the pasture as fertility increases. At Cowra the results have been more promising; a marked reduction in the growth of skeleton-weed under competition from pasture plants has been recorded and it seems evident that there will be a progressive decrease in skeleton-weed density. In contrast to the Canberra results, grass has not been a significant factor in skeleton-weed competition at Cowra.

(iii) *Competition between Hoary Cress* (Cardaria draba (*L.*) *Desv.*) *and Cereals.*—The successful control of hoary cress by two applications of phenoxyacetic acid compounds at one- or two-year intervals has been repeated in large-scale field experiments in the Wimmera District of Victoria. The greater effectiveness of the second application in comparison with the first has been demonstrated at dosages as low as ¼ lb. of active ingredient per acre. Increases in cereal yields did not always occur in the year of spray application, but yields were invariably higher in the following spraying.

(iv) *Competition between Pastures and Hoary Cress.*—The significance in hoary cress control of the increase in the density of volunteer annual grasses recorded following spray applications of 2, 4-D and "Methoxone" is being investigated. Results to date indicate that Wimmera ryegrass (*Lolium rigidum* Gaud.) reduces the density of hoary cress but that its effect is less marked than that of the spray application in this respect.

(v) *Eucalypt Regeneration in Fire-breaks.*—The maintenance of fire-breaks in a condition in which they are not likely to carry fire is an important problem in forests. In many areas the regeneration of eucalypts by suckering following bulldozing of the original stand is creating a maintenance problem. The Division has commenced co-operative studies with the Australian Timber and Forestry Bureau in the Australian Capital Territory on the control of suckers by chemical methods.

(vi) *Distribution of Introduced Plants in South-eastern Australia.*—Studies of the distribution of introduced weeds has continued, special attention being given to the relationship between soil type and the occurrence of particular species. Laboratory studies on the germination requirements of a number of species and field experiments on the effect of fertilizers and time of sowing (temperature) on the species which establish are in progress. Work has also commenced on studies of the biological factor in germination and competition between individual weed species.

(vii) Nasella trichotoma *(Yass River Tussock)*.—The ecology of the invasion of *Nasella* into natural and sown pastures has been investigated. Herbicides were tested to reduce stands, and low rates of application of sodium trichloroacetate (25 lb./acre) have been successful in eliminating mature stands. Invasion of natural pastures in excellent condition is common on the established field trials, but no invasion of sown pastures can be induced when superphosphate is applied annually at 2 cwt. per acre. These trials are on rough hill country where cultivation is not possible and which is typical of areas where *Nasella* is the main problem. The control of *Nasella* using sodium trichloroacetate at these rates is of major practical interest, but the method has proved unreliable under certain rainfall conditions.

The need for rain following spraying of this herbicide was established several years ago, and work is now proceeding to eliminate this source of unreliability. Further trials have been laid down: these mainly consist of testing other herbicides and varying formalities of those previously tested, and improving techniques of establishing pastures on rough hill country.

(viii) *General Weed Control.*—Routine testing of commercial and experimental selective herbicides and soil sterilents on important weeds is being continued as new materials and techniques appropriate to a particular need become available.

(*g*) *Grazing Management Experiment (Mitchell Laboratory, Trangie)*.—This project, which is being conducted in co-operation with the New South Wales Department of Agriculture, is designed to obtain information on management problems of the semi-arid *Chloris* pastures using various percentages of grazed lucerne as a supplement. A number of severe floods early in 1956 prevented any results of this project being obtained this season.

(*h*) *The Distribution of Natural Communities in Relation to Soil Nutrients.*—Comparisons of the soils of natural communities have so far been confined to those which occur on neighbouring sites. Five suitable paired communities were selected, and soils obtained from each of the ten sites. Pot culture experiments using oats and subterranean clover as test plants are used to determine differences in nutrient status of the soils of each of the two communities. Concurrently or subsequently, as circumstances permit, nutrition trials with the particular *Eucalyptus* species occurring as dominants in each of the communities are made in pot cultures, the objectives being both to determine the effects of the nutrients on the individual species, and to ascertain whether any element or elements has a differential effect on these species. On the results obtained, a field trial can be designed to determine whether plant nutrients play a significant role in competition between the eucalypts on a particular site. For example, it has been shown that there is a significant difference in the amount of available phosphorus in the soils of the *E. polyanthemos* and *E. melliodora* woodlands, there being more available phosphorus in the former than in the latter. A nutrition trial with the two species suggests that it is possible that *E. polyanthemos* has a higher phosphate requirement than *E. melliodora.*

(*i*) *Microclimates and Topography.* — Preliminary studies have commenced at Canberra on the ranges of factors of the microclimate on various slopes and aspects. It is intended to use the information obtained for studies of plant establishment and growth.

(*j*) *Growth Studies.*—An investigation was undertaken to obtain information on suitable methods of estimation of yield and also on various growth characteristics of four species. The species used were *E. polyanthemos, E. melliodora, E. fastigata,* and *E. bicostata.* It has been shown that for trees up to twelve months old there is a good correlation between yield and leaf area. Significant correlations between yield and height and height X diameter have also been obtained.

15. BIOCHEMISTRY AND BIOPHYSICS.

(Division of Plant Industry.)

(*a*) *Biochemistry of Growth and Cell Differentiation.*—Work on the biochemical processes underlying cell growth and cell differentiation, particularly the role played by nucleic acid components, has been developed as follows:—

(i) *Growth of Isolated Roots of Subterranean Clover.*—While higher plants are in general wholly autotrophic, isolated organs are not. The labour of biosynthesis of many diffusible substances is divided among the various organs. Aseptic culture of isolated tissues permits a study of which substances must normally be supplied from other parts of the plant. Under favourable conditions it indicates tissues suitable for studying the steps in the pathways of biosynthesis of certain metabolites. It also provides a means of studying the direct morphogenetic effect of exogenously added substances.

Preliminary studies of the exogenous nutrient requirements of isolated roots of a number of species have been made. Subterranean clover has been studied in close detail. For the growth of the primary apical meristem, the pH optimum is 5.5 to 6.0, the temperature optimum is 25° C., and the optimal sucrose concentration is 1.5 per cent. There is an absolute requirement for nicotinic acid, and growth is promoted by adding thiamin, pyridoxine, L(+) arginine, L(+) glutamine, and L(+) asparagine, and possibly other yet unidentified substances in yeast extract. In the best media devised, initial growth rate of the root exceeds that in the intact seedling, but no treatment has yet permitted repeated subculture of the primary apex at a sustained high rate of growth.

Subterranean roots exhibit a strongly "dominant" growth form. No lateral roots emerge within 5 to 8 cm. from the main axis tip, and no laterals within 20 to 30 cm. of the tip grow at a rate comparable with that of the primary tip. The lateral roots are much thinner and the meristems more sluggish than in the case of the primary apex. Excised lateral meristems (commonly used in propagating clones of isolated roots of other species) nearly always fail to grow.

Casein hydrolysate (140 mg./1.) has a striking effect in promoting the growth of the laterals. As their growth rate suddenly increases, they thicken and the zones of cell division and cell elongation become much longer. When these lateral meristems are excised, their chance of survival is greatly increased. Casein hydrolysate, at lower concentrations, promotes the growth of the primary meristem. At concentrations *supraoptimal* for the primary meristem, the lateral meristems are stimulated to grow rapidly. Thus the two kinds of meristems are favoured differentially by different concentrations of casein hydrolysate.

(ii) *Nucleotide Synthesis in Plants.*—These studies have been continued but results are yet in a preliminary stage. Work of Greenberg, showing the accumulation of 4-amino-5-imidazole carboxamide and its rioside in sulphonamide-inhibited *E. coli*, was repeated. Similar experiments using *Chlorella* have failed to reveal the presence of these compounds, though growth is similarly inhibited by sulphonamides (50 per cent. inhibition at about 8 x 10^{-5}M). Pea seedlings grown in 8 x 10^{-5}M sulphathiazole were extracted, and the extracts were chromatogrammed on paper. Four diazotizable (primary aromatic) amines appeared in the inhibited plants. One of these is probably 4-amino-5-imidazole carboxamide and the others are not yet identified.

(iii) *The Physiological role of IAA Oxidase.*—This enzyme system has now been well studied by many workers, but no convincing physiological role has been assigned to it. Being one component determining tissue IAA concentrations, its activity may be expected to influence IAA-induced growth.

Some specific stimulants and inhibitors for the oxidase have been applied in growing test systems, and the effect on growth measured. Further experiments are necessary before any interpretation can be made.

(iv) *Isolated Epidermal Cell Cultures.*—In earlier work, excised flax hypocotyls were used to study the initiation and organization of adventitious meristems, arising in response to excision. Buds are derived adventitiously from meristems arising from the renewed division activity of *mature* cells in the epidermis. It has been found to be possible to pull off the epidermal layer in a single-celled sheet. Attempts will be made to cultivate these isolated cells under conditions where they may undergo cell division.

(*b*) *Crystalline Yeast Lactic Acid Dehydrogenase* (*Cytochrome b_2*).—The minimal molecular weight of the enzyme on the basis of the haem content was estimated to be 97,000. As ultracentrifugal analysis has indicated a homogeneous protein of molecular weight 100,000-200,000, the enzyme in solution probably exists as a monomer or dimer.

A polynucleotide component comprising 5 per cent. of crystalline enzyme dry weight was extensively studied. The sugar component proved to be deoxyribose, and the proportions of bases detected were adenine (0.41), guanine (0.11), cytosine (0.15), and thymine (0.33). Base, sugar, and phosphorus were present in equal proportions. As the nucleotide of the intact enzyme was hydrolysed by deoxyribonuclease but not ribonuclease, it was assumed to have the conventional deoxypentose nucleic acid structure.

Nucleotide removal by enzymic hydrolysis or salt dissociation did not affect lactic dehydrogenase activity, but the nucleotide-depleted enzyme could not be crystallized.

Unsuccessful attempts were made to demonstrate phosphate esterification (" oxidative phosphorylation ") during lactate oxidation by solutions of the complete enzyme.

Studies on enzyme inhibition showed that metal ions, particularly copper, were the main cause of instability, probably through oxidative destruction of a flavine-protein linkage. Ethylenediaminetetra-acetate (" Versene ") was effective in enzyme protection.

(*c*) *Biophysics.*—Measurements have been made of surface potential differences in plant cells. When complete, these measurements will indicate whether the postulate of an external membrane (plasmalemma) with differential permeability for potassium, chloride, and hydrogen ions can be substantiated. These and other studies to be undertaken will be of interest in understanding the entry of substances, both nutrient and poisonous, into the cells, and their retention and transport.

(*d*) Duboisia myoporoides.—A sample of *Duboisia myoporoides* from southern Queensland has been found to contain two alkaloids not previously known to be found in this species. The major alkaloid in the bulk samples examined has been identified as partly racemic anabasine. The other base appears to be identical with the alkaloid pelletierine found in the root and stem bark of *Punica granatum.* As pelletierine is the active principle of pomegranate bark which has been used since ancient times as a taenicide, its occurrence in this geographical variety of *Duboisia* may be of economic importance. The alkaloid is readily obtained in larger yield from this source than from pomegranate bark.

16. PHYTOCHEMICAL SURVEY.

(Division of Plant Industry.)

Since the appointment of a full-time field botanist by the Division of Industrial Chemistry, the direct participation of the Division of Plant Industry in phytochemical collections has been reduced. Co-operation through editing of Conference proceedings, and general supervision of field activities, has continued.

17. PASTURE INVESTIGATIONS, CANBERRA.

(Division of Plant Industry.)

(*a*) *Pasture Utilization.*—The aim of pasture utilization is the co-ordination of the feed requirements of grazing animals and the production of such feed by pasture plants, so that a high degree of efficiency of conversion of plant food into animal products may be achieved. Investigation of this aspect of pastures necessitates the study under field conditions of the effects of the animal on plant communities and of the grazed material on the animal.

One of the main factors limiting the number of livestock that can be carried on an area of land is the length of the periods of inadequate feed as measured either on a quantitative or qualitative basis. At an annual stocking rate limited by the periods of inadequate feed, insufficient animals are present to utilize any more than a proportion of the feed present in periods when there is more than sufficient. It has been shown that a large wastage of nutritious feed occurs when climatic conditions are unfavorable to plant production or sustenance. Besides the limitations imposed on the numbers of animals that can be carried, the varying amount and quality of feed seriously affect the productive performance of the individual animal.

Evidence is being sought of the effect on animal production of insufficient feed supplies during the winter, and of poor quality supplies during the summer, by using various pasture and animal practices. Adaptation of plant output to best suit animal intake and of animal intake to best fit pasture production is being examined in a number of experiments. These include the effect on annual production of attempting to level out pasture or crop production or both, or usage by mechanical processes (hay conservation, silage conservation, grain storage), by pasture management methods, and by the interposition of crops to provide out-of-season grazing. Adaptation of animal needs to fit the varying plant supply is being studied in terms of type or types of animal, time of reproduction, effect of limitation of intake at specific physiological periods, &c.

(i) *Pasture Conservation.*—Long-term studies of the behaviour of the pasture and of the animals grazing on it under various forms and intensity of pasture conservation are being continued. Heavier wool yields and increased meat production are being sustained on pastures where excess growth is conserved and fed back when feed is in short supply. Data are accumulating on the effect of such practices in altering the botanical composition of the pasture and on the reaction of the animal arising from these changes. In addition, more detailed experiments of a shorter-term nature to elucidate the causes of the botanical change have been conducted.

(ii) *Pasture Management.*—Previous work by the Division failed to substantiate any pasture or animal benefit from rotational grazing as compared to continuous grazing. Recent trials using dry sheep have failed to show any advantages in wool production and liveweight gain from autumn-saved pastures. An examination of the effect of autumn-saved pasture on breeding ewes is now being conducted.

(iii) *Interposition of Crops.*—One effect of the sale of crop products is to reduce the available nitrogen in the soil for subsequent pasture development. This is being examined in a comprehensive trial to determine the effects of such procedure on the ability of the clover constituent to rapidly replace the lost nitrogen, and to compare the effect of such clover dominant pastures on the grazing animal.

(iv) *Animal Adaptation.*—The pasture management trial referred to above will, in addition, measure the effect on the ewe and on two types of lamb of restricted intake during portion of pregnancy, and of increased availability of feed during lactation. A preliminary study has already been completed of the comparative effects of native and improved pasture under various forms of management on the milk production from Merino ewes and the effect on lamb growth.

18. Pasture Investigations, Armidale.

(Division of Plant Industry.)

(*a*) *Ecological Survey.*—With the exception of several small areas yet to be covered, the field work in connexion with the ecological survey of the New England region is complete. Detailed reports on the climate, soils, geology, topography, and natural vegetation and the interrelationships of each are being prepared.

(*b*) *Pasture Ecology and Autecological Studies.*—Studies of the effects of winter burning of ungrazed native pasture have shown that the most marked effect is in reducing the density of the annual grasses. Perennial grasses are affected much less. Annual burning for four years resulted in a 27 per cent. reduction in basal cover of perennial grasses. With burning in alternate years the reduction was only 17 per cent.

From a study of the seasonal variations in nitrogen, sulphur, phosphorus, and calcium levels of the more important species in the native pasture an assessment has been made of the adequacy of these nutrients in the grazing provided for sheep. For dry sheep it appears that the calcium level would be adequate throughout most of the year, but phosphorus, crude protein, and sulphur would be bordering on deficiency during late autumn and winter, and during dry summers.

(*c*) *Grazing Management Studies of Native Pastures.*—An experiment in which the effect of various summer management practices, including heavy stocking with sheep, stocking with cattle, mowing, burning, and the incorporation of clovers on the winter production of the pasture has now been concluded after four years of study. In brief, the results indicate that whatever the summer treatment, the straight native pasture produced poor results from Merino weaners during the winter. Where clover had been introduced into the native pastures the weaners made good growth throughout the winter.

A comparison of the breeding performance, wool production, and liveweight gains of sheep offered different proportions of supplementary grazing on sown pasture has been made to give an indication of ways of increasing production for native pastures. Increased liveweight gains by weaners were recorded for each increase in the proportion of sown pasture from the lowest (4 per cent.) to the highest proportion (57 per cent.). Similarly increased wool production and percentage of lambs born and marked were obtained with increasing proportions of sown pasture.

(*d*) *Improvement of Native Pastures.*—It has been found that native pastures on non-arable land can be greatly improved by the incorporation of clovers. It is possible that an even greater improvement could be obtained if high-quality forage grasses could be established in the same manner. However, such factors as the competition from native grasses and low initial soil fertility may make this difficult. It is planned to study these problems in a series of experiments which have just commenced.

The possibility of increasing the rather poor and slow establishment of clovers surface-seeded into native pastures by insecticidal treatment of the seed before sowing has been investigated. An improvement in establishment of about 20 per cent. has been obtained by the use of chlordane dust.

(*e*) *Species and Strains Trials.*—Lucerne has grown well at most sites and, as a legume for use in utilizing the moisture available from the summer rains, is the most promising. The good performance of subterranean clover on the more western sites indicates that the environmental limits of this species have not yet been reached.

Phalaris tuberosa has been the best grass species. However, following fertility improvement by clovers, other grasses are coming into prominence. In the east, cocksfoot and *Phalaris arundinacea* have been somewhat more productive than *P. tuberosa*. Two fescue species have also done moderately well.

In a comparison of various species mixtures under grazing, Merino weaners made greater liveweight gains on a pasture of Demeter fescue and white clover than on pastures of *Phalaris tuberosa* and white clover or perennial ryegrass and white clover. An average stocking rate of 6.8 weaners per acre was maintained on these pastures. It varied from 5 per acre in winter to 12 per acre in late spring and early autumn, and 8 per acre in summer.

(*f*) *Ley Pastures.*—The winter productivity under grazing of various short-term pastures and oats is being studied. Wimmera ryegrass and Tallarook subterranean clover have been more productive than short-rotation ryegrass, oats, crimson clover, and red clover. The yield of oats declined considerably over a four-year period despite the fact that the crop was grazed *in situ*.

(*g*) *Plant Nutrition Studies.*—The improvement of the quality and productivity of native pastures by increasing the productivity of native legumes through the use of fertilizers has been investigated in a pot experiment. The response of six native legumes to phosphorus and sulphur singly and together was compared with that from naturalized legumes and subterranean and white clovers. The yield of native legumes was doubled where both phosphorus and sulphur were applied, but it was still low. The yield of naturalized legumes was increased about eight times over that from native legumes when phosphorus and sulphur were applied.

The survey of the plant nutrient status of the soils of ie New England region has progressed a stage further by ie inclusion of four more sites. Recent results confirm iose reported earlier, namely, that—

(i) Nitrogen is deficient in all soils tested.
(ii) Phosphorus is the main deficiency on the podzolic and solodic soils, irrespective of the parent material from which they are derived, although a less acute deficiency of sulphur also exists in these soils.
(iii) Sulphur deficiency is most severe in soils derived from basalt and in kraznozems derived from laterite. No plant growth response to calcium, potassium, magnesium, or any of the trace elements has been recorded, with the exception of a slight response to boron at one site.

With the object of effecting economy in the use of uperphosphate, an experiment is in progress to investigate vhether the production of a pasture can be maintained y making an initial application of superphosphate and hereafter meeting the annual nutrient requirements by ipplying gypsum. Pasture yields taken in the second year of this experiment showed that an initial dressing of 2 cwt. per acre of superphosphate had a low residual value. However, an initial dressing of 8 cwt. per acre iad a high residual value. On a basaltic soil where narked responses by a natural pasture to an application of gypsum was previously reported, some response was still evident after three years.

(*h*) *Clover Nodulation.*—Sowings of subterranean clover in new land are often poorly nodulated in the first year despite conventional methods of inoculation of the seed. During the year a re-examination was made of the effect of a number of factors known to be of importance n ensuring nodulation. Among these were methods of placement of inoculum, methods of neutralizing the superphosphate applied with the seed, supply of nutrients, and supply of energy. None of the treatments involving these factors had any effect on nodulation. Other treatments calculated to increase the numbers of organisms added to he soil, such as the use of massive doses of inoculum or he addition of soil from an area where subterranean clover was established, gave a high percentage of nodulated plants.

(*i*) *Sulphur Studies.*—As a preliminary step in a letailed study of sulphur in the soil-plant-animal complex, nvestigations of sulphur in soils have been commenced. Analytical techniques for the rapid and accurate determinations of total and sulphate sulphur have been studied. Methods have been devised which overcome the various objections to accepted standard procedures, and these are now being tested over a wide range of soils. Marked lifferences have been noted in the two soils so far studied in detail. The potential for adsorption of sulphate by some soils may be very great.

19. PASTURE INVESTIGATIONS AND AGRICULTURAL PHYSICS, DENILIQUIN.

(Division of Plant Industry.)

(*a*) *Agricultural Physics.*—Advances have been made in this field in the theoretical treatment of isothermal soil-water phenomena. A relaxation solution of the Stokes-Navier equation and a study of the tensorial nature of permeability have led to advances in understanding of the validity of Darcy's Law. An investigation has also been made of the influence of inertia effects on the limits of this law.

A quantitative physical understanding of infiltration has been made possible by solving the general partial differential equation describing water movement in unsaturated porous materials. Mathematical methods have been published for solving the concentration-dependent diffusion equations describing water movement in horizontal (absorption) and vertical (infiltration and capillary rise) porous systems. By treating the water in the soil, the plant, and the atmosphere as a thermodynamic continuum it has been possible to set up a biophysical model of the processes of normal transpiration and of temporary and permanent wilting.

A theoretical and experimental investigation has commenced on the influence of advection on the microclimate and energy balance under irrigated conditions to assses quantitatively the influence on an irrigated area of air moving into it from surrounding unirrigated land. This should provide improved methods for estimating the water needs of irrigated areas.

(*b*) *Ecology.*—Two separate studies on the ecology of the Riverine Plain dealing with the physical factors of the soil which affect the distribution of species have been completed. In the gilgai microrelief the factors operating in distributing species between the shelf, the puff, and the depression appear to be the soil moisture content at which water becomes available to plants and particularly to seed, the intensity of soil cracking which influences seed retention, moisture penetration, the extent to which root systems are damaged, and the aeration of the soil.

Emphasis is now being placed on the ecology of the pasture species grown under irrigation. During winter the soil space available for air in Riverina clay is below 10 per cent. for extended periods. It seems probable that inadequate aeration is responsible for poor winter growth of irrigated pasture. It has been shown this year that high concentrations of carbon dioxide for eight days cause stalling of Wimmera ryegrass during that period and reduces the dry-weight production by half compared with that of plants grown in a normally aerated culture, or in a culture where available oxygen was reduced by 75 per cent. Plants which stalled during periods of high carbon dioxide supply grew normally and rapidly as soon as normal aeration was resumed.

(*c*) *Agronomy.*—Of thirteen pasture species grown under natural rainfall conditions for four years the most productive and persistent have been Wimmera ryegrass, barrel medic, and lucerne.

Medicago intertexta and *M. ciliaris* also showed promise for alkaline clay soils during 1955. Eight of the most promising species, including those mentioned above, are being put out this year to determine the production of herbage during the winter and of edible pods for summer. The influence of seed size on establishment and on production is also being studied.

Medicago tribuloides and subterranean clover were best established into natural pastures on Riverina clay after heavy cultivation. Competition from weeds and the native pasture species was not sufficiently restrained by a light cultivation. Surface sod seeding was unsatisfactory owing to competition from other species.

(*d*) *Pasture Utilization.*—Further digestibility trials were conducted to investigate the mathematical relationship for organic matter digested and feed nitrogen intake, with faecal nitrogen.

It has been reported earlier that on a paspalum-cocksfoot-white clover pasture where food intake for sheep was rationed during the autumn, the body weight increase per acre was inversely related to stocking rate but that this relationship did not hold for wool production. The increased efficiency of utilization for wool production when intake is rationed is an important feature for managing irrigated pastures.

(*e*) *Genetics.*—A trial has been commenced to establish the performance of Canadian hybrid creeping rooted lucerne and Hunter River type lucerne on clay soil under dry and irrigated conditions. The Hunter River type has yielded six cuts in the season and the hybrid has yielded three cuts. The wet season gives no valid comparison between the irrigation and dry treatments.

Areas of mixtures of strains and mixtures of hybrids of subterranean clover were sown during 1955 at Deniliquin, Oaklands, Tooleybuc, and Euston as indicated in last years' Report. In spite of a good season and good initial establishment at Euston, yields were low and regeneration in 1956 is scant. Tooleybuc regeneration is good on heavy soil and poor on light soils, and at Deniliquin and Oaklands regeneration is good on both light and heavy soils.

(*f*) *Animal Production.*—Work on the heritability of twinning in Merino ewes has been done in co-operation with the Division of Animal Health and Production.

20. PASTURE INVESTIGATIONS IN WESTERN AUSTRALIA.

(Division of Plant Industry.)

(*a*) *Grazing Management of Annual Pastures.*—A point of general interest arising from the comparison of continuous and autumn-deferred grazing on a subterranean clover pasture at Perth is that losses of dry pasture during summer are much greater than can be accounted for by animal consumption. These unaccounted-for losses are due primarily to trampling by the sheep and are most noticeable when the pasture residues at the beginning of summer are high. The use of meadow hay conservation to reduce these losses is being examined.

(*b*) *Studies on Perennial Grasses.*—(i) Phalaris tuberosa.—The study on the effect of row spacing on yield and persistence has been continued. Over the period 1950-55 (inclusive) the wider-spaced rows, 35 and 49 in., have consistently produced more herbage per plant than the 7- and 21-in. rows.

A further trial involving four strains of *Phalaris tuberosa* with and without fertilizer nitrogen is proceeding. Results from the second year (1954) are now available. In all strains, plant persistence was considerably improved by either applied nitrogen or supplementary irrigation. There was no evidence of interaction. With respect to production of herbage, however, there was a very marked positive interaction between nitrogen and supplementary irrigation. Coupled with this was a reduction in yield of associated annuals in the autumn-winter period. In spring, both the perennial and annual species responded to the above treatments. The longer growing season appears to have conferred a relative advantage on the perennial grass in the year following the irrigation treatment.

The effects of waterlogging on *Phalaris* seedlings are being studied in pot culture. Waterlogging *per se* is not necessarily adverse. It is detrimental, however, when *Juncus bufonicus* is grown in association with the grass. Another problem with *Phalaris tuberosa* is the mortality during the first summer with late spring transplanting. This does not seem to be simply related to moisture supply. The possibility that reserve carbohydrates are implicated is being examined.

(ii) *Other Grasses.*—The four perennials, *Hyparrhenia hirta, Phalaris tuberosa, Ehrharta calycina,* and *Oryzopsis miliacea* are being studied under intermittent grazing at Perth and Kojonup, both with and without applied fertilizer nitrogen. *Phalaris tuberosa* and *Ehrharta calycina* are both under rotational grazing at Kojonup. Results so far have shown firstly, the extreme selectivity of sheep grazing on the veldt grass pasture, and secondly, better maintenance of body weights of sheep during summer on the *Phalaris* pasture.

The building up of a non-shedding strain of *Ehrharta calycina* by means of the polycross test is proceeding. Generally speaking, the performance of perennials at Kojonup has been disappointing. One possible reason for this is the restricted root development on Balgarup sandy loam, on which most of the work has been conducted. Several grasses will therefore be examined on other soil types more favourable to root development.

(*c*) *Species and Strain Trials with Annuals.*—(i) *Subterranean Clover*—The single plant studies at Kojonup are nearing completion. Data based on a large number of strains grown over several seasons have confirmed earlier work at Adelaide in that total production is highly correlated with maturity. However, in contrast to the Adelaide work, it was found that seed production was also positively correlated with maturity. An explanation for this apparent discrepancy is being sought during the 1956 growing season. The main differences in total productivity between strains seem to be accounted for by time of maturity. Indeed, after averaging the five years' productivity data, and adjusting these for maturity, no differences between strains reached significance.

Under sward conditions, the early strain Dwalganup has been outstanding for seed production at Kojonup. However, further information, using a large number of strains, is being sought during 1956.

(ii) *Brome Grasses.*—Plots of the four species of *Bromus* and eight strains of *B. mollis* were established during 1955. Continuous grazing will commence in May, 1956.

(*d*) *Plant Nutrition Studies.*—(i) *Pot Culture Trials, Perth*—Utilization of phosphorus from three sources (superphosphate, tricalcium phosphate, and rock phosphate) by several legumes during early growth has been investigated. Two trials were conducted, one in winter (under glass) and one in summer (out-of-doors). No marked differences were found between the two strains of subterranean clover—Dwalganup and Bacchus Marsh—in their reaction either to source or level of applied phosphorus. Barrel medic, on the other hand, appeared sensitive to low levels of phosphorus. Lupins showed the least relative response. However, the alleged superiority of lupins in utilizing phosphorus from rock phosphate was not supported in these trials.

(ii) *Field Trials, Kojonup.*—The influence of season on zinc response in subterranean clover is still under investigation. Again, in 1955 responses to zinc were negligible. The reasons for the marked responses in the first year only of this trial (1952) are still obscure.

The residual effects of superphosphate and rock phosphate on a subterranean clover pasture is still under examination. Pasture production on the plots receiving high initial dressings of rock phosphate outyielded the corresponding superphosphate plots in 1955 (fourth year of trial). However, percentage utilization of phosphorus from the rock of phosphate has remained low at approximately 4-6 per cent. A comparison of annual applications of superphosphate with single initial dressings is being made on two soil types. The trial will be completed at the end of the 1956 growing season.

Marked sulphur responses were observed in two experiments during 1955; both of these have been in progress for several years. In a third trial, of more recent origin, responses were negligible. There has been a steady increase in the severity of sulphur deficiency on subterranean clover pasture, starting *de novo*. This may result either from leaching, or (more likely) from decreased availability of the "native" soil-sulphur due to its incorporation in soil organic matter.

(*e*) *Ecology of Annual-type Pastures.*—Long-term seasonal effects on botanical composition changes under grazing are continuing at Kojonup. Despite the high mortality of subterranean clover seedlings after the February rains in 1955, this species grew well during the winter months. The possibility that leaching of soil nitrogen promoted clover growth requires examination. Mortality of clover (and also of silver grass and capeweed) seedlings after the early autumn rains in 1956 was also heavy. Seedlings of ripgut brome grass and *Erodium botrys* evidently possess superior drought resistance.

(*f*) *Soil Fertility Investigations.*—In last year's Report, it was mentioned that striking increases in total soil nitrogen were observed in an acutely phosphorus-deficient subterranean clover pasture. Indeed, the rate of increase was quite out of line with the production of the legume. This high rate—equivalent to approximately 70 lb. N/ac/year—has continued during the fourth growing season. No satisfactory explanation has yet been advanced, and in view of the unexpected results, confirmation will be sought in a further field trial commencing during 1956. An auxiliary pot culture trial will also be conducted at Kojonup.

Two experiments have been in progress since 1952, in which wheat is continuously grown on areas previously under clover pasture. Soil nitrogen levels have remained fairly uniform over the four years, but cereal yields have declined steadily. Turning in the cereal stubble has (in most instances) reduced yields more than either burning or removal of stubble. The trials will be continued for a further two seasons.

21. PASTURE INVESTIGATIONS IN SOUTH-EASTERN QUEENSLAND.

(Division of Plant Industry.)

I. Regional.

(*a*) *Coastal Lowlands.*—(i) *Ecology*—Some field observations on coastal islands have yet to be made, but most of the coastal lowland survey is complete. The preparation of an integrated series of papers under the general title "The Ecosystem of the Coastal Lowlands of Southern Queensland" is in hand. Separate geological studies have been made to help in providing a satisfactory interpretation of the results of the major survey.

(ii) *Pasture Species and Mixtures.*—The significance of the occurrence of poorly drained gley soils and drought-susceptible sandy laterities in a mosaic pattern at Beerwah has been accentuated. It is apparent from harvest figures that the season of maximum growth is widely different for these two soil types. The lateritic soils produce well in wet spells, and the gleys in drought. This feature could favourably affect the seasonal distribution of pasture production from the region as a whole. White clover was nematode infested on lateritic sand but unaffected on gley.

Trials to estimate the nitrogen contribution to pastures by various legumes have indicated *Desmodium uncinatum* and *Indigofera endecaphylla* as valuable species in this respect. *Stylosanthes* has given disappointing results, but *Desmodium intortum* and *D. sandwichense* show promise. In a replication of 36 simple grass and legume mixtures yields of 2,800 lb./ac. of dry matter were obtained from the best.

The trial on nutrient limitation, particularly nitrogen, on a *Paspalum dilatatum* sward at Caboolture has shown that high herbage yields (up to 12,200 lb./ac.) can be obtained with a generous nitrogen supply, but that protein yield (1,200 lb./ac.) and nitrogen recovery (30 per cent.) were low compared with European results.

Study of variation in white clover showed a range in morphological characters and yields, with Ladino most productive, New Zealand and Irrigation intermediate, and Louisiana least productive.

(iii) *Plant Nutrition.*—The nutrient status of the soils of the Beerwah experiment area is now known. Plant nutrition work is becoming increasingly directed to the problems of pasture maintenance rather than establishment. Yield data and foliar deficiency symptoms indicate a need for repeated dressings of phosphate and potash, especially to mixed grass and legume swards. The reason for the necessity of frequent fertilizer application is not yet clear. Growth depression following the use of acidic fertilizer and the cause of anthocyanin pigmentation in white clover (a suspected boron deficiency symptom) remain to be investigated. Soils from the Bundaberg area show similar deficiencies in respect of nitrogen, phosphorus, potassium, calcium, and sulphur to those at Beerwah, but no response to trace elements is apparent.

(*b*) *Spear Grass Region.*—A soil survey by officers of the Division of Soils has established the existence of prairie and solodic soils as the two main soil groups carrying spear grass in the Rodd's Bay experiment area.

In species selection work at Rodd's Bay, *Phaseolus lathyroides, Stylosanthes gracilis,* and *S. bojeri,* continue to show superiority in yield and persistence, and have spread by seeding, especially *P. lathyroides. Alysicarpus bupleurifloris,* a native annual legume, has assumed importance in the experimental area probably as a result of phosphate application. *Chloris gayana, Paspalum commersonii,* and *Paspalum plicatulum* continue to do well among grasses. Others of the *Paspalum* genus show promise, but *Cenchrus ciliaris* and *Panicum maximum* (var. *tricholglume*) have been disappointing.

New grazing trials on 15-acre blocks using *Phaseolus lathyroides* sown with both *Paspalum commersonii* and *Chloris gayana* have given good liveweight gains during the winter period, in contrast to weight losses on native spear grass.

Plant nutrition investigations have shown responses to phosphorus, sulphur, molybdenum, and calcium carbonate, on Rodd's Bay soils. Although large increases in yield resulted from applications of either sulphur and molybdenum or calcium carbonate, the calcium response appears unrelated to molybdenum, and there is no response to sulphur in the presence of the heavy dressing of calcium carbonate. In trials using *Phaseolus lathyroides* and *Trifolium repens,* both phosphorus and sulphur deficiencies were confirmed in soils at "Brian Pastures". Calcium response occurred only with *Trifolium repens.*

(*c*) *Sown Pastures on Black Soils* (Cooper Laboratory, Lawes).—An experiment has been commenced on the immediate and residual effects of heavy dressings of ammonium sulphate on yield and carrying capacity of *Paspalum commersonii* pastures in pure stands and associated with *Medicago sativa* in rows. Grass top-dressed with 10 cwt. ammonium sulphate had double the carrying capacity of unfertilized grass plots (from 3.2 to 6.4 sheep/acre), in the first season. Grass with associated *M. sativa* gave an appreciably smaller increase in carrying capacity. Trials to establish the optimum nitrogen dressing for *Paspalum commersonii* swards have shown no additional response above 7 cwt. ammonium sulphate/acre, or its equivalent.

(*d*) *Sown Pastures on Sandstone Ridge Soils* (Cooper Laboratory, Lawes).—Evidence that *Medicago sativa* and *Medicago tribuloides* can be established on the sandstone ridge soils of the Bundamba and Marburg series, if their nutrient and rhizobial requirements are met, is now conclusive. With applications of superphosphate, molybdenum, and lime, *M. sativa* has persisted for three years, and *M. tribuloides* has shown vigorous natural regeneration. Boron deficiency has been recorded in both pot and field experiments with *M. tribuloides,* and has adversely affected seeding. The applications of lime needed to establish these legumes may aggravate the boron deficiency.

Phaseolus lathyroides can be grown on these soils without lime if molybdenum is supplied; the addition of lime can induce zinc deficiency symptoms in this species. *M. sativa, M. tribuloides,* and *P. lathyroides* have shown copper response in pot trials, but this has yet to be confirmed under field conditions.

(*e*) *Brigalow Scrub Region* (Acacia harpophylla).—Pasture improvement work involving research in agrostology, agronomy, and plant nutrition in the brigalow region began in 1955. Brigalow (*Acacia harpophylla*) associations occur chiefly between the 20- and 30-in. isohyets in a tract extending 750 miles in a north-south direction from Collinsville in Queensland to Gunnedah in New South Wales; 16,000,000 of an estimated 23,000,000 acres remain undeveloped. The highly fertile brown to gray calcareous clays support agriculture and dairying in closely settled areas, and sheep and beef cattle elsewhere. Development has been simplified by large-scale mechanical and chemical methods of clearing.

Three experimental sites have been chosen along a north-south transect of Queensland. They include typical areas of the three major soil types of different geological origin on which brigalow is found. Each centre has an average annual rainfall of about 25 inches, predominantly of summer incidence; the southern centre has reliable rainfall, well distributed with a significant winter component; the northern centre has less reliable rainfall, with no significant winter component.

Studies of establishment and growth, and evaluations of productivity of strains of the grasses *Chloris gayana, Cenchrus ciliaris, Panicum maximum, Panicum coloratum,* and of selected species in the genera *Paspalum, Digitaria,* and *Urochloa,* and of legumes in the *genera Phaseolus, Crotalaria, Centrosema, Clitoria, Desmodium,* and *Medicago* are being made. A number of recent plant introductions are included in these trials. Pasture mixture studies will be conducted on combinations of the most promising grasses and legumes. This work is being conducted on three properties located in the north, central, and southern brigalow scrub region.

Pot culture trials on brigalow soils and the other major soil types associated with brigalow country in the central and southern regions have been designed to establish the macro- and micronutrient status in these soils. Some correlation is sought between the nature and degree of deficiencies, the geology of the soil parent material, and the various characters of the different soil types.

II. General.

(*a*) *Plant Nutrition.*—Marked differences in specific responses to nutrients have been observed among legumes. Genera of temperate origin, e.g. *Trifolium* and *Medicago,* have shown a response to calcium and copper many times greater than that observed in those of tropical origin, e.g. *Indigofera, Desmodium,* and *Phaseolus.* Work on specific response to nutrients is being extended. Further studies of the foliar symptoms of deficiency and excess of individual nutrients have been conducted. Critical values of potassium and phosphorus for *Trifolium repens* have been established. This work will be extended to cover other species, and correlation between water culture results and pot and field experiments will be sought.

In a comparison of sources of phosphate the value of rock phosphate as compared with superphosphate for several temperate legumes was ascertained, and a wide specific variation found. *Medicago* genus appears to have superior capacity to *Trifolium* in utilizing rock phosphate. Local sources of potassic fertilizer have also been investigated. Response was obtained only from calcined alunite, while trachyte, glauconite, and potassium alum gave no response in the first season.

(*b*) *Plant Chemistry.*—Investigation of the occurrence of β-nitropropionic acid in several species of *Indigofera,* with particular attention to *I. endecaphylla,* has continued in conjunction with *Indigofera* plant breeding work; a semi-quantitative paper chromatographic technique, developed in this laboratory, is being used to estimate the content of this compound. Only moderate variation of the compound within this species has been found, although it is absent from certain *Indigofera* species—e.g. *I. tettensis* and *I. retroflexa.* Toxicity tests, in association with the Queensland University Veterinary School, using mice as test animals, have been made of both acute and chronic toxicities, by using synthetic β-nitropropionic acid, and aqueous extract of *I. endecaphylla,* of known β-nitropropionic acid content. The organic and amino acids of several *Indigofera* species have been investigated, with the object of determining the role of β-nitroproprionic acid in the metabolism of the plant.

The presence of a new imino acid, with properties closely corresponding to those of 5-hydroxypipecolic acid recently isolated by Steward at Cornell, has been detected in soluble nitrogen fractions of *Leucaena glauca.* This acid is chromatographically identical with 5-hydroxypipecolic, and traces of hydroxylysine, a possible precursor, have been found in young *L. glauca* leaves. This investigation, and the survey of *L. glauca* strains for mimosine content, are being continued.

Recoveries of phosphorus, potassium, calcium, and magnesium in the new analytical technique for estimation from a single digest have been of the order of 97-100 per cent., and these microtechniques can now be used with confidence.

(*c*) *Plant Physiology.*—The study of the function of potassium in plants has continued, with particular attention to discovering the precursor of putrescine in conditions of potassium starvation. The diamine putrescine occurring in potassium-deficient barley and *Trifolium pratense* is known to be the direct cause of deficiency symptoms. *Trifolium repens* and *Trifolium subterraneum* have been examined semiquantitatively for free amino acids, and full quantitative analysis is to follow. Evidence to date indicates that putrescine may be formed from arginine, although ornithine cannot be ruled out as a precursor. Carbon-marked amino acids are being used to obtain evidence on this point. Possible influence by other ions on putrescine accumulation cannot be ignored, as low potassium content can influence the quantitative uptake of other ions. This possibility suggests a wider field of research than can be at present undertaken in detail, but the analyses of the calcium, phosphorus, potassium, and magnesium contents of normal and deficient plants now in progress may help to clarify the situation.

Work on the effect of the sulphur deficiency on free amino acid content has been extended to include *Desmodium uncinatum, Phaseolus lathyroides, Trifolium repens,* tomato, flax, and barley. Increases in free amino acids have been found in all the legumes examined, the most pronounced increases being in arginine, asparagine, and glycine. Aspartic and glutamic acids were, however, reduced in quantity. In tomato, flax, and barley a larger increase in total free amino acids was noted under conditions of sulphur deficiency, but the changes in individual amino acids were not consistent between these species.

(*d*) *Legume Bacteriology.*—A collection of 350 strains of *Rhizobium* now covers a wide range of legumes, with tropical and subtropical strains predominating. Development of a rapid screening technique for nodulating ability, using *Phaseolus lathyroides* as a test host, has made speedy transfer of new isolates from the " presumptive " to the " confirmed " category possible. A modification of the Leonard technique for comparative testing in the greenhouse has been adopted. Superior growth of tropical species has been obtained by replacing the neutralizing mixture and acid nutrient solution with vermiculite and a simple mineral nutrient solution. More than 500 cultures of tested *Rhizobium* strains were supplied to colleagues during the year for use in field and glass-house experiments.

Examination of the nodulation process in *Stylosanthes* indicates a similar pattern to *Arachis;* root hair infection plays no part in nodule initiation.

Theoretical considerations of the host-*Rhizobium* symbiosis, coupled with an examination of the botanical relationships in the order Leguminosae, gave rise to a hypothesis concerning the origin of the symbiosis which forms a basis for a systematic reassessment of the subject. Many cross-inoculation phenomena can be explained by this hypothesis, which gives first importance to the " cowpea " type of *Rhizobium* as representing the ancestral and typical condition.

(*e*) *Plant Breeding and Genetics.*—The study of "little leaf" virus disease in a wide range of sub-tropical legume introductions has been completed. In conjunction with an officer of the Division of Entomology the insect vector (*Orosius argentatus*) was defined. Existence of sufficient species and strains with field resistance to "little leaf" was proved, and a breeding programme for resistance seems unnecessary.

Studies of modes of pollination in *Phaseolus lathyroides*, *Indigofera endecaphylla*, *Desmodium uncinatum*, *Stylosanthes gracilis*, and *Leucaena glauca* were completed. All are self-compatible, but need high humidity for pollen tube growth in the stigma. *P. lathyroides* and *S. gracilis* are cleistogamous, but some natural cross-pollination is possible in others studied.

X-ray dosages of 10,000 to 20,000 r have been used on seedlings in efforts to induce variation in such important species as *Paspalum dilatatum*, *Paspalum commersonii*, *Phaseolus lathyroides*, and *Indigofera endecaphylla* where the natural mutation rate is low. In the case of *I. endecaphylla* a mutant low in β-nitropropionic acid is sought. Attempts to cross this species with *I. retroflexa* and *I. tettensis*, which are free from the compound, have been made.

Attempts at interspecific crossing in the genera *Phaseolus* and *Desmodium* have yielded no definite positive results, but an apparent cross between *P. semi-erectus* and *P. lathyroides* has been made. A study of variation in *Leucaena glauca* has resulted in the identification of early, mid-season, and late flowering types. The two later types are taller, less branched, and wintergreen, and a cross-breeding programme between them and the early free seeding types is planned.

Sorghum almum populations have been tested for cyanogenetic activity. This species shows a range in variation for this character, and it should be possible to select types of little or no cyanogenetic glucoside content.

The naturally cross-fertilizing genera *Setaria* and *Digitaria* are receiving detailed attention. The high degree of variation present gives opportunity for selecting winter production types on a phenotypic basis. The possibility of developing allopolyploids is being investigated.

The allopolyploid *Phalaris tuberosa* x *P. minor* is continuing to segregate, and perennial and annual types are being selected. A range of rhizamatous lucerne selections has been made, and these are being intercrossed to develop populations for selection under grazing.

(*f*) *Pasture Species—Feeding Values* (Cooper Laboratory, Lawes).—Feeding value studies of a number of sub-tropical grass and legume species fed at different growth stages using Merino x Border Leicester wethers have been made. The feed was chaffed and fed to individually penned animals. Sufficient data on *Urochloa pullulans*, *Panicum maximum*, and *Paspalum commersonii* are available for a comparative study of nutritive values. A highly significant relationship between dry matter intake and protein content has been established. The increase in dry matter intake which occurs with the feeding of supplementary protein in the winter period when protein in mature herbage falls below maintenance level is highest in *P. commersonii* and lowest *in U. pullulans* of the three species compared.

Mature *P. commersonii* gave protein analyses below 3 per cent. but the analyses in the other species did not fall below 4 per cent. *Paspalum commersonii*, although the superior grass in digestibility when protein supplements are available, falls below maintenance requirement for a longer period than *U. pullulans* or *P. maximum*. This work indicated much lower starch equivalents necessary for maintenance than that indicated by English standards.

Feeding trials with *Chloris gayana* and *Cenchrus ciliaris* showed them to have a superior winter feeding value to *P. commersonii*, *P. maximum*, or *U. pullulans*. A feeding trial with legumes showed mature *Desmodium uncinatum* to be superior to mature *Phaseolus lathyroides* in palatability and intake. *Crotalaria lanceolata* was not readily eaten, and *Stylosanthes gracilis* was shown to be inferior to *D. uncinatum* in feeding value.

An experiment comparing the effect of differential stocking rates on the nutritive value of feed obtained from pastures previously ungrazed, lightly grazed, and heavily grazed, has been completed. Mature and slightly frosted *Paspalum commersonii* and *Panicum maximum* were fed. *P. maximum* was most digestible in the moderately grazed area, while *P. commersonii* showed no significant variation between treatments. Results indicate that grazing intensity is of minor importance in determining nutritive value in comparision with stage of maturity.

22. BIOPHYSICAL RESEARCH.

(University of Tasmania.)

The Organization is supporting the work of the Biophysics Laboratory by providing finance for a postgraduate studentship and a grant for general laboratory purposes. During the past year the studentship has been vacant.

The following investigations are being undertaken by the Biophysics Group.

(*a*) Further study of the electric field pattern associated with plant roots is being made. The conditions under which the root generates electric oscillations are being considered and a mechanism involving negative feedback has been postulated to account for them.

(*b*) A method has been devised to measure the ionic concentration of chlorine in the vacuole and cytoplasm of the living *Nitella* cell. This is done by implanting two microprobes in the cell; one containing potassium chloride and the other being a silver/silver chloride microelectrode.

(*c*) The organization of plant tissue following wounding is being studied. Adventitious buds in the epidermis of decapitated flax seedlings are being damaged by wounding the apex, and the subsequent regeneration is examined.

IV. IRRIGATION.

1. GENERAL.

The production of crops under irrigation requires specialized techniques, and the continued application of water to the soil can result in problems not encountered in dry-land agriculture. The deterioration of land under irrigation is a world problem of great magnitude.

For the study of ways in which irrigated land can be made to keep its fertility, and waterlogged land can be reclaimed, the Organization has two Irrigation Research Stations: the Commonwealth Research Station (Murray Irrigation Areas) at Merbein, Victoria, on the Murray River, and the Irrigation Research Station (Murrumbidgee Irrigation Areas) at Griffith, New South Wales. The work of these two Stations is reported in this chapter.

Research into soils and their behaviour under irrigation has been carried out at both Merbein and Griffith in close co-operation with the Division of Soils (*see* Chapter II.).

Studies of irrigated pastures are carried out at Deniliquin, New South Wales, by the Division of Plant Industry (*see* Chapter III., Section 19), and other investigations of irrigation techniques for northern tropical areas are carried out by the Land Research and Regional Survey Section at the Kimberley Research Station near Wyndham, Western Australia (*see* Chapter XI., Section 3). Work on dried vine fruits in progress at the Commonwealth Research Station, Merbein, Victoria, is reported in Chapter XIII., Section 14.

Irrigation Research Stations.—During the past year, research has been concentrated chiefly on problems associated with the development of high ground-water levels and with soil salinity under irrigation, and on factors influencing yields of irrigated crops. Other investigations include: Physiological processes associated with water stress in plants, factors influencing quality of citrus, dried vine fruits, and tomatoes, and the occurrence and control of nematodes parasitic on plants in irrigation areas. Increased attention is being given to methods by which the suitability of new areas proposed for irrigation may be assessed and to the principles for selection of the most appropriate crop to which individual portions of such land could be devoted.

Changes in administration of the Stations include the appointment of Mr. D. V. Walters as Technical Secretary, and the retirement in June of Mr. E. S. West from the position of Officer-in-charge of the Irrigation Research Station, Griffith. Mr. West had occupied the position since the Griffith Station was first formed in 1923.

The Water Conservation and Irrigation Commission of New South Wales continues as a partner in the Griffith Station, making an annual contribution to funds. On certain aspects of ground-water hydrology in the Murrumbidgee Irrigation Areas, officers of the Commission and the Organization are working in close co-operation.

Merbein Station retains close touch with the dried vine fruits industry, which makes annual contributions to funds through the Commonwealth Dried Fruits Control Board, the Mildura Packers' Association, Co-operated Dried Fruits Sales Pty. Ltd., and the Nyah-Woorinen Enquiry Committee.

Hydrological investigations have been conducted on the farm acquired during 1954-55 by the Swan Hill Irrigators' Research Committee. A further step in this type of regional activity has been taken by the recent purchase of a farm by the Kerang Agricultural Research Committee, on which the Merbein Station is represented. This farm will be available for purposes of investigation and demonstration.

2. MERBEIN.

(*a*) *Irrigation, Soil Preservation, and Reclamation.*—Observations on ground-water levels through the Renmark district were continued. Heavy rains during 1956 led to fewer irrigations and as a result these levels in autumn were unusually low. The bores penetrating to aquifers under areas of heavy soils are no longer being pumped, as studies revealed that they were not sufficiently effective. No trouble has been experienced with tile drains placed in Bookmark loam in 1954 where tiles were laid with screening and supporting material to overcome the difficulties of the unstable sandy subsoil. Heavy irrigations have been used to leach this soil. Vines which were affected by salt before the drains were installed are now growing vigorously.

Using new equipment to handle 3-in. casing, a pumping test was conducted on the Swan Hill Irrigators' Committee farm. Previous deep boring had shown the complexity of the distribution of sand strata under this farm, which is close to the Murray River. Some of these deep-lying sands have good hydraulic conductivities. The physical properties of the subsoils in part of the farm are such that those parts have been assessed as suitable for tile drainage.

In co-operation with the State Rivers and Water Supply Commission of Victoria, three sites at Red Cliffs were tile drains have been installed are being examined for the relationship between water-table levels, hydraulic conductivity of the soil, drain depth and spacing, and drain discharge.

Deterioration of irrigated land in the vicinity of Wakool due to rise in ground-water has emphasized the importance of regular observations of ground-water levels. Such observations, interpreted in relation to the many local facts which have a bearing on them, provide opportunity for applying corrective measures before extensive soil damage ensues. Observations of ground-water levels and determinations of salinity and other features of soil and underlying strata are part of the long-term programme of investigation on the irrigated pasture plots of the Wakool Land Use Committee. Widely scattered ground-water observations in this district by the Water Conservation and Irrigation Commission of New South Wales provide a basis for relating the ground-water situations on the experimental plots to those of the district in general.

(*b*) *Land Use.*—To assist in the development of new lands for irrigation, the Research Station has carried out several local soil surveys, comprising 1,170 acres for horticultural use and 300 acres for pasture.

Soil sampling has been done before onset of irrigation on a new area of pasture plots being established on Moragh loam, an important soil type of the now-developing Deniboota Irrigation District. These plots, designed to aid in decisions for land use in the district, are part of the extended activities of the Wakool Land Use Committee.

(*c*) *Horticulture.*—First related by work at Merbein Station many years ago to the percentage of fruitful buds found in canes in the dormant period nine months before harvest, yield of the sultana vine has now been related to the amount of sunshine in the spring eight months earlier still. When this finding is considered together with the effect of biennial bearing, a new insight becomes possible into the problem of annual yield variation in the vine. The sunshine effect could operate through the carbon to nitrogen ratio in the plant. This idea might assist in explanation of inconsistent results previously obtained from investigations on nitrogen nutrition of the vine.

Established five years ago at the Research Station, a field trial of cultivation methods for sultana land gave as good yield in the past season from " no cultivation " (weeds controlled by oil spray) as from control (ordinary cultivation, with winter cover crop), while white clover sod yielded less. White clover sod turned in eighteen months previously increased yield nearly a quarter over control.

The fruitfulness of sultana buds in May, 1955, was found to be 52 per cent., which promised a slightly higher than average crop. Severe frosts in parts of the settlement and extremely unfavourable weather at harvest reduced total district yields substantially. Frost occurred on 17th and 18th September, and its effect was studied in three vineyards. Bud burst was almost complete by then and about half the shoots were damaged. Approximately a further 10 per cent. of the buds produced shoots subsequently, and only one quarter of them was fruitful. The yield from these vines was smaller than would have been expected from the number of bunches remaining.

In May, 1956, the fruitfulness was 43 per cent. For the first time, the fruitfulness assessment has been used to predict an average district potential yield for sultanas. This has been estimated at 32 cwt. per acre for harvest in March, 1957.

The pruning trial in which the the number of buds per sultana vine was varied and the number of buds per cane was kept constant was concluded after its sixth year. By varying the number of canes per vine according to the potential fruitfulness found before pruning, overloading in very fruitful seasons could be avoided and some improvement to the crop could be achieved in years of low fruitfulness. However, complete uniformity of crop from year to year could not be obtained.

Splitting of grape berries was further studied. Up to a certain stage of maturity, detached currant and sultana berries immersed in water took up water without splitting. Thereafter, splitting was associated with water uptake. Enclosure in plastic bags of dry currant bunches on the vine showed after 24 hours a high percentage of split berries and condensation within the bags. This indicates the importance of a saturated atmosphere.

(*d*) *Plant Nutrients.*—The nutrient requirements of the sultana vine in the field are the subject of several trials and of chemical work on the plant and soil material from the trials.

The most comprehensive trial, now in its 21st year, is on the Research Station itself, and compares all combinations of ammonium sulphate, potassium sulphate, and superphosphate, each at 4 cwt./ac., with and without green manure. In most years there has been an increase in yield of dried fruit with ammonium sulphate, although no such increase was found this year. In the last six years there has been a trend towards increasing responses from superphosphate, but the increases rarely have been significant.

Response of the sultana vine to nitrogen status of the soil has been inconsistent in other trials commenced in recent years. Maximum nitrogen status was aimed at with 4 cwt. per acre of ammonium sulphate together with a green manure crop; minimum status was attempted by depletion through growing barley and carting it off. Sulphate of ammonia was applied at all combinations of early spring, late spring, and autumn. In these trials, leaf nitrogen was increased by an ammonium sulphate application in early spring, but a yield increase did not necessarily follow. So far it has proved impossible to establish analytically a general foliar nitrogen level indicative of nitrogen deficiency.

Yield of sultanas has not been affected, in one trial, by either urea applied as a foliage spray or ammonium sulphate applied to the soil for comparison. High concentrations of urea spray (1 per cent. in mid October to 3 per cent. in early December) did no apparent damage and increased the nitrogen content of the leaves considerably.

(*e*) *Vegetables.*—" Krilium " as a soil improver failed to increase yield or give earlier ripening of glass-house tomatoes in two years' trial on a Curlwaa loam. Similar negative results were obtained in one season's work on a much heavier soil. " Krilium ", however, made the soil easier to cultivate.

Several crosses have been made to develop lines of glasshouse tomatoes of improved agronomic quality and resistant to some of the common diseases—root knot nematode, fusarium wilt, and leaf mould.

Further progress in the breeding programme has been made in selection of field tomato hybrids resistant to both root knot nematode and fusarium wilt. Bulk seed of several promising hybrids has been obtained and released to selected growers for comparison with popular local varieties and for yield trials.

(*f*) *Nematology.*—The field management trial at Red Cliffs for control of root knot in tomato now embraces sixteen treatments involving combinations of fallow, barley cover crop, *Crotalaria*, susceptible and resistant tomatoes, and peanuts. Improved yields due to crop rotation were obtained in the fifth season. In plots planted to resistant tomatoes for five successive seasons, about two-thirds of the plants showed root knot infection in 1955-56. It has been confirmed that the predominant root-knot nematode in the trial area is *Meloidogyne javanica*, but growing of peanuts has revealed a slight infestation with *M. hapla* not previously recorded.

A small nematode control trial was commenced on Grenache vines infested with root knot and root lesion nematodes. Although some reduction of soil nematode populations appears to have been achieved by insecticidal drenches and fumigation, neither these nor sawdust mulching appear promising for practical purposes.

(*g*) *Dried Vine Fruits.*—The work of the Commonwealth Research Station, Merbein, on dried vine fruits is reported in Chapter XIII., Section 14.

3. Griffith.

(*a*) *Soil Salinity.*—Factors associated with salt accumulation and occurrence in farms of the Murrumbidgee Irrigation Area have been studied by reconnaissance survey. A linear relation was found between soil permeability and " mean depth of chloride " (a measure of distribution and concentration of chloride). Topography is also important. Surface salt concentration is high in local depressions and at the lower slopes of local hills. This is due apparently to high content of salt in the virgin state and to development and height of water-tables as affected by seepage.

Irrigation methods also have an influence associated with differences in distribution of irrigation water. Flood irrigated pastures are virtually free from salt accumulation. Vineyards furrow-irrigated over most of the soil surface show less surface salt than citrus grooves where furrows are restricted to narrow bays. Lucerne has a special effect; it lowers the water-table, allowing leaching of salt. High quality of irrigation water and the relatively high winter rainfall in recent years are also important factors in the present distribution of salt in these soils.

Investigations have revealed that as a rule no chemical amendments are necessary for reclamation of salty soils in Mirrool Irrigation Area. Salt composition was determined on 23 profiles on the principal soil types of the Area. These soils are classified as saline and saline-alkali soils.

Studies of the effect of a short period of salinity stress on citrus are reported below. It appeared desirable to follow this work with studies of salting on a quicker-growing crop. A trial has been commenced to select suitable barley varieties of differing salt tolerance. Further work should reveal reasons for varietal differences in salt tolerance.

(*b*) *Horticulture.*—The factorial experiment with citrus was continued on Farm 466. This experiment involves four different varieties, four cultural treatments, and four nitrogen treatments (as ammonium sulphate). While yields in the sod and bare surface treatments were increased by nitrogen fertilizer, fruit quality was adversely effected. This year the decline in quality with increasing nitrogen was also noted in the tilled treatments. Information on the development and correction of soil acidity induced by applications of sulphate of ammonia as fertilizer is being obtained by superimposing graduated applications of lime over the nitrogen treatments in the field experiment and by laboratory examinations of soil samples from the experiment for pH, exchange capacity, and exchangeable cations including ammonium.

Work on the relationship between phosphorus deficiency and poor fruit quality, reported last year, was supplemented by a third farm trial laid out with phosphorus and lime as treatments.

(*c*) *Plant Physiology.* (i) *Plant/Water Relations.*—Water shortage is the ever-recurring and overriding limitation imposed on most Australian agriculture. Even in our areas of good rainfall and those under irrigation, crops and pastures suffer intermittent water stress. A study of such stress, and recovery from it, could make valuable contributions to basic physiology and provide practical leads to the farmer, plant breeder, water supply engineer, and microclimatologist.

Studies have been continued of the effects of a brief period of water shortage on nitrogen, protein nitrogen, and phosphorus in the young tomato plant including its principal parts, individual laminae, and petioles.

Wilting caused two compensatory trends in nutrient content: that during, and that subsequent to, wilting. Effects were strongest in the nutrient content of the more actively growing organs. During wilting, the uptake of nitrogen and phosphorus was markedly reduced. Both nutrients were translocated from the laminae to the stem. Upon re-watering, active uptake of both nutrients was resumed and both passed preferentially to the laminae rather than to the stem. The net result was a depression of nutrient content for the whole plant. In the more actively growing parts, nutrient content regained control levels.

The depression of nutrient content was initiated relatively early in the drying cycle. As reported previously, dry weight also was depressed early in the drying cycle.

More detailed studies appeared desirable and have been commenced; dry-weight data are to hand. Fractionation of phosphorus compounds, now in progress, is a preliminary to determining what is first hit in the chain of metabolic processes. It will, however, be necessary to use controlled temperature, humidity, and lighting for future studies.

(ii) *Salt Intake*.—The high content of salt in the leaves of the saltbush (genus *Atriplex*) is well known. An outstanding feature of the indigenous xerophytic members of the genus, such as perennial and old-man saltbush, is the extraordinarily large amounts of sodium chloride taken up. Leaves of some experimental plants have contained 40 per cent. of their dry weight as sodium chloride, while others have survived and grown in water cultures containing molar sodium chloride.

This work, a continuation of studies commenced at Sydney University, aims to study in detail this salt intake phenomenon and its effects on the anatomy, mineral nutrition, and water relations of the plants.

Work on the xerophytic species is being balanced to some extent by comparable experiments on an introduced halophytic species, *A. hastata*. Leaf and root material from completed water culture experiments are being analysed for sodium, potassium, and chloride.

(iii) *Growth Experiment with Citrus*.—Fruit set was achieved only eight months from roots developing on cuttings of Washington Navel oranges in sand and soil in a glass-house trial. The growth pattern was studied over several cycles of growth. Nutrient distribution within the plant, including its roots, was traced by chemical analyses for nitrogen, phosphorus, calcium, magnesium, and chlorine. Treatment comparisons have been made for water shortage, for nitrate and ammonium as nitrogen sources, and for response to a brief period of exposure to high salinity.

Significant effects of water shortage on nutrient content have been observed. There was also a significant difference in uptake of both nitrogen and phosphorus when the alternative sources of nitrogen were compared. Presumably because the growth rate of citrus is slow even in sand culture, no significant growth responses to a brief salinity stress were found. Analyses of the different plant parts, however, showed that chlorine which had entered the plant during treatment remained in leaves present at that time and passed to newly developing leaves from the stem and the root.

(*d*) *Land Drainage*.—A study of permeability of horticultural soils in the Area revealed that permeability of subsoils is largely dependent on soil texture and relative density. The hill slope areas have a highly developed and stable structure in the subsoil, and it is only in these that soil structure is important in relation to permeability. Impermeable layers have been located and defined in certain areas through this study—a matter of importance in designing tile drain installations.

Interpretation of soil permeability in terms of texture, relative density, and structure has been an important aid in correlating permeability values obtained by the auger hole method with those obtained by the piezometer method.

Recommendations for tile drainage are now based on soil permeability as the major factor determining the feasibility of such drainage and the spacing of tile laterals in land to be drained. Depth at which tile is laid is determined by the occurrence of an impermeable layer. Desired rate of drainage, climatological and hydrological data, and economic considerations are other factors entering into design of tile systems.

Actual behaviour of tile drain installations on selected local farms has been checked against the behaviour expected from designs based on soil permeability surveys by the auger hole method and on some design factors at present estimated provisionally. In this study, drain discharge and water-table levels over the whole drained parts of the farm are recorded together with such relevant data as rainfall and irrigation. In addition to overall check on design, this work aims to evaluate tile drain factors, such as discharge coefficient and drainable porosity now estimated. The investigations, conducted in association with the Water Conservation and Irrigation Commission of New South Wales, will continue for at least a year on each farm, to cover at least one complete irrigation season and one winter.

The home farm of the Irrigation Research Station was investigated in considerable detail in regard to the groundwater situation and subsoil permeability. It has been found that portions of the farm are suitable for tile drainage.

When hydraulic conductivity of soil is not the same in every direction, the soil is described as anisotropic. Natural soils are usually of this kind. An important contribution to the study of soil anisotropy in relation to land drainage has been made from Merbein Station. Field studies on the subject are in progress from Griffith Station to specify the degree and causes of anisotropy in local soils. A special 6-in. diameter piezometer, sufficiently light for easy handling, has been found satisfactory for this work.

V. ANIMAL HEALTH AND PRODUCTION.

1. General.

The Division of Animal Health and Production is responsible, within the framework of the Organization's programme of research into problems of the animal industries, for investigations concerned with animal health and reproduction and with general animal husbandry. The importance of live-stock production to the national economy cannot be too strongly stressed and any increase in knowledge in this field ultimately affects every member of the Australian community.

The head-quarters of the Division is located in Melbourne but its activities are spread throughout the Commonwealth. Reports on the work in progress are presented in this chapter and in Chapters VII. and VIII.

The work of the Division of Biochemistry and General Nutrition on nutritional problems is reported in Chapter VI. Section 12 of this chapter deals with investigations of the Animal Genetics Section other than those on sheep and cattle which are included respectively in Chapter VII., Section 15 and Chapter VIII., Sections 8 and 9.

Division of Animal Health and Production.—The established investigational programme was followed, with certain modifications, during the year. The Committee of Management has continued to assist the Chief effectively, in matters of divisional research and administrative policy. In conjunction with the preparation of the annual estimates, there is also a meeting of the Committee of Management with the Officers-in-charge of all Sections of the Division, when research, administrative, and financial affairs are discussed in some detail. To streamline administrative procedure, arrangements have been made to give the larger sections a greater degree of autonomy.

Dr. F. H. S. Roberts, Officer-in-charge of the Veterinary Parasitology Laboratory, Yeerongpilly, has proceeded overseas to observe recent research developments in connexion with external and internal parasites of cattle. He will attend an F.A.O./O.I.E. meeting on the "Control of Tick-borne Diseases".

A Cattle Tick Research Committee has been set up to review progress in this important field of work. Dr. I. M. Mackerras is chairman, and members include representatives of the Divisions of Animal Health and Production, and Entomology; the Department of Agriculture, New South Wales, and the Queensland Department of Agriculture and Stock.

Grateful acknowledgement is made of financial assistance received from the wool industry, the Australian Meat Board, and the Australian Dairy Produce Board.

2. ANIMAL HEALTH RESEARCH LABORATORY, MELBOURNE.

(Division of Animal Health and Production.)

At this laboratory, investigations of some major diseases of sheep and cattle have been continued; these include studies on certain infectious diseases and microbial metabolism of some of the causal organisms. In addition, the general and chemical pathology of some non-infectious diseases, such as those following ingestion of poisonous plants or the grazing of pasture plants under natural conditions, have received further study. The main investigations are—

Kimberley horse disease and studies on poisonous plants (*see* Chapter V., Section 11); toxicity of large rations of wheat (*see* Chapter VII., Section 12); infertility and physiology of reproduction in sheep (*see* Chapter VII., Section 13); "toxaemic jaundice" of sheep (*see* Chapter VII., Section 17); brucellosis of sheep (*see* Chapter VII., Section 17); pleuro pneumonia of cattle (*see* Chapter VIII., Section 2); mastitis in dairy cattle (*see* Chapter VIII., Section 2); haematuria vesicalis of cattle (*see* Chapter VIII., Section 2); infertility in dairy cattle (*see* Chapter VIII., Section 2); brucellosis of cattle (*see* Chapter VIII., Section 2).

3. MCMASTER ANIMAL HEALTH LABORATORY, SYDNEY.

(Division of Animal Health and Production.)

The construction of the Ian McMaster Wing has commenced and will be completed before the close of 1956. This extension will accommodate Divisional Head-quarters, the Library, and staff engaged in research on sheep breeding and selection. It will alleviate the present congestion in the main building after the vacated rooms are converted to laboratories.

An officer of the Division of Statistics is stationed at the McMaster Laboratory, and his assistance in the planning and the interpretation of experiments is greatly appreciated.

Dr. I. W. Parnell is spending at least two years at the laboratory to work on parasitological problems. His visit was made possible by funds from the Ian McMaster Bequest. Mr. Ansari, G.B.V.C., a Colombo Plan Fellow of Pakistan, is spending three months in the Parasitology Section.

Dr. R. T. Clark, co-ordinator of beef cattle research in the United States Department of Agriculture, is centred at the McMaster Laboratory during tenure of a Fulbright Fellowship.

The major problems investigated at the Laboratory are a study of the heritability of fleece characteristics (*see* Chapter VII., Section 14); studies on internal and external parasites of sheep (*see* Chapter VII., Sections 18 and 19); drought feeding and the utilization of low-quality roughage (*see* Chapter VII., Section 11); fattening of beef cattle (*see* Chapter VIII., Section 7); biochemical studies, particularly in relation to vitamin A (*see* Chapter VII., Section 11); certain infectious diseases of sheep (*see* Chapter VII., Section 17); and the fundamental cause of deaths in sheep due to exposure after shearing (*see* Chapter VII., Section 17).

The Officer-in-charge, Dr. D. F. Stewart, was President of the Australian Veterinary Association for 1955-56.

4. VETERINARY PARASITOLOGY LABORATORY, YEERONGPILLY, QUEENSLAND.

(Division of Animal Health and Production.)

This laboratory was established in 1948 to undertake investigations into parasites affecting live-stock, particularly those of importance in Queensland. Up to the present, attention has been directed mainly to parasites of cattle. The laboratory also provides accommodation and facilities for officers of the Division of Entomology who are engaged in investigations into the control of the cattle tick *Boophilus microplus*. Facilities for field work are provided at the Laboratory's Field Station, "Amberley", near Ipswich.

Co-operation with the Queensland Department of Agriculture and Stock is maintained and is assisted by the Joint Veterinary Parasitology Committee.

Investigations in progress include studies on: parasitic gastro-enteritis of cattle (*see* Chapter VIII., Section 3); host reactions to tick infestation (*see* Chapter VIII., Section 4); and protection against blowfly in sheep (*see* Chapter VII., Section 20).

5. F. D. MCMASTER FIELD STATION, BADGERY'S CREEK, NEW SOUTH WALES.

(Division of Animal Health and Production.)

The season in this environment was a most difficult one. The rainfall during the winter and early spring months of 1955 was low, but after October, an extremely wet period commenced, 42 inches of rain falling in the next six months. This produced conditions which were unfavorable to crops, pastures, and stock.

The work with dairy cattle is reported in Chapter VIII., Section 6. Other investigations in progress are: inbred flocks of Australian Merinos (*see* Chapter VII., Section 14); inheritance of component fleece characters (*see* Chapter VII., Section 14); studies on twins (*see* Chapter VII., Section 14); the relation between growth of lambs and future production (*see* Chapter VII., Section 14); and coat shedding studies on cattle (*see* Chapter VIII., Section 6).

6. SHEEP BIOLOGY LABORATORY, PROSPECT, NEW SOUTH WALES.

(Division of Animal Health and Production.)

Since the initiation of research at Prospect in 1953, there has been steady progress in developing the research programme and the necessary physical facilities. A second animal house for experimental sheep is under construction and plans have been completed for the main laboratory block.

The major investigations at this laboratory are: metabolism of pregnant ewes (*see* Chapter VII., Section 10); physiology of reproduction (*see* Chapter VII., Section 13); breeding and genetical studies (*see* Chapter VII., Section 14); and biological studies of skin and wool growth (*see* Chapter VII., Section 16).

The installation of equipment for the climate rooms, mentioned in the last Report, is nearly complete and testing has begun; these rooms will provide a wide diversity of controlled climatic conditions and thus facilitate the study of the physiological mechanisms by which the sheep responds to its environment.

During the year, part of the staff of the Tracer Elements Group, formerly at the Chemistry School of the University of Melbourne, was transferred to the Sheep Biology Laboratory. Methods of detecting radioisotopes using several types of Geiger-Müller tube and autoradiography are now in routine use. The gas-counting method for the assay of carbon-14 and tritium is being developed. The measurement of tritium by liquid scintillation counting has been attempted, but reproducible counting rates have not yet been attained, evidently owing to insufficient voltage stabilization and high background counting rates. The equipment required to overcome these difficulties is on order. Work has been commenced on the use of 35S-sulphate as an inert marker for measuring the rate of passage of small particles through the sheep's rumen, and on the use of radioactive iodine (^{131}I) for the study of the pituitary hormones concerned in wool growth. Many chemical and physiological tracer experiments must await the installation of facilities for handling relatively large amounts of radioactivity.

The Fleece Analysis Laboratory continues to provide a service for the physical measurements of fleece and cattle hair samples. A total of 26,904 measurements were made during the year. Ninety-eight per cent. of these measurements were on fleece samples, and included determinations of yeild, clean wool weight per unit area of skin, fibre density, mean fibre diameter and length, staple length and crimp, and chemical fractionations of greasy wool samples. The other 2 per cent. consisted of samples of cattle hair on which determinations of weight of hair per unit area of skin, mean fibre length and diameter, and examinations for medullation were made. These measurements were made for research projects within the Division.

7. REGIONAL PASTORAL LABORATORY, ARMIDALE, NEW SOUTH WALES.

(Division of Animal Health and Production.)

The Regional Pastoral Laboratory at Armidale and its associated Field Station, " Chiswick ", were established in 1947. At present, the research team consists of officers of the Divisions of Animal Health and Production, Plant Industry, and Mathematical Statistics, and of the Wildlife Survey Section.

Investigations in progress by officers of the Division of Animal Health and Production include: studies on lamb mortality (*see* Chapter VII., Section 13); double joining of ewes (*see* Chapter VII., Section 13); distribution of lambing performance (*see* Chapter VII., Section 13); sheath rot in wethers (*see* Chapter VII., Section 17); internal parasites (*see* Chapter VII., Section 18); grazing management (*see* Chapter VII., Section 22); and beef cattle (*see* Chapter VIII., Section 7). " Chiswick " was one of the centres used in the Merino Strains Trial and progress in this work is reported in Chapter VII., Section 14.

Based on a detailed ecological survey of the New England region, the Division of Plant Industry has an extensive pasture research programme in progress. It includes plant introduction studies, studies on native pastures, problems of plant nutrition, and the development, maintenance, and utilization of sown pastures. Investigations in progress by the Wildlife Survey Section include survey of insect vectors of the myxoma virus, and methods of rabbit control (*see* Chapter X., Section 2).

At " Chiswick " an area of 1,100 acres has been cultivated and sown to pasture. In addition, approximately 900 acres of native pasture have been cultivated and surface-seeded with grasses and clovers. Sheep shorn in 1955 totalled 4,855, yielding 127 bales of wool, or an average of 8.2 lb. per head, including crutchings. A total of 1,500 lambs were weaned in March, 1956; cattle totalled 145 head, and horses ten.

8. NATIONAL FIELD STATION, " GILRUTH PLAINS ", CUNNAMULLA, QUEENSLAND.

(Division of Animal Health and Production.)

The rainfall recorded at the station during 1955 was 20 inches, which is 7 inches greater than the yearly mean for Cunnamulla. As a result, there was no period during the year in which the natural pastures were unsatisfactory for sheep.

At shearing in the autumn of 1956, medium Peppin ewes fifteen to sixteen months old cut 10.8 lb. of greasy wool, during a calculated growing period of twelve months.

Two of the Merino breeding trials previously reported are being continued, namely, AB1 and the study of the inheritance of hornedness in sheep (*see* Chapter VII., Section 14). The strains trial was completed during the year (*see* Chapter VII., Section 14).

9. NATIONAL CATTLE BREEDING STATION, " BELMONT ", ROCKHAMPTON, QUEENSLAND.

(Division of Animal Health and Production.)

" Belmont ", situated on the Fitzroy River some 20 miles north of Rockhampton, was acquired by the Australian Meat Board and made available to the Organization in 1953 for work on beef cattle production. The main programme of the station, which is 7,000 acres in area and has a carrying capacity of 1,400 head, is directed towards studies in adaptation of British breeds and their crosses with exotic breeds to a tropical environment.

The first set of matings were made in January 1954, and these have been successfully repeated in 1955 and 1956. To date, calvings have been good and, with the completion of extensive facilities necessary for the handling of large numbers of cattle to meet experimental requirements, comprehensive data are now being accumulated on many aspects of production.

Generally, seasonal conditions have been favorable and, although some minor disturbances have resulted from unusually frequent floods, the main programme has not been upset and all experimental groups have been held intact.

Improvement of the property by way of ringbarking, scrub clearing, eradication of noxious weeds, and sowing down of pastures, is proceeding satisfactorily.

Although some surplus animals have been disposed of, stock numbers have now reached 1,300.

Preliminary results and a progress report is given in Chapter VIII., Section 8.

10. POULTRY RESEARCH CENTRE, WERRIBEE, VICTORIA.

(Division of Animal Health and Production.)

Studies in population genetics, with particular emphasis on problems of heterosis, and supported by physiological research, form the main projects at this Centre. Progress reports are given in this Chapter, Section 11.

A total number of 1,253 dams were selected during the 1955 breeding season and artificially inseminated with semen from 119 selected sires. The total population of adult birds was reduced to save expenditure on feed and at April 1, 1956, was 5,250 of which 3,028 were White Leghorns, 483 Australorps, and 1,739 crossbreds of various types.

11. INVESTIGATIONS OTHER THAN WITH SHEEP AND CATTLE.

(Division of Animal Health and Production.)

In addition to work at the main centres described in previous sections of this chapter, staff of the Division are also located in Western Australia, South Australia, Queensland, and Tasmania, working in association with Departments of Agriculture and Universities. Work is proceeding at the University of Adelaide in genetics (*see* this Section); at the University of Queensland on the effects of high temperature on pregnancy in Merino ewes, on breeding season of Merino ewes in relation to length of day (*see* Chapter VII., Section 13), and on seasonal coat changes in cattle of European origin (*see* Chapter VIII., Section 7); with the Western Australian Department of Agriculture in Perth on the copper metabolism of sheep (*see* Chapter VII., Section 17), and on the comparative biochemistry of copper and on the cobalt status of pastures (*see* this Section); with the Northern Territory Administration and

Department of Agriculture, Western Australia, on the investigation of Kimberley horse disease (*see* this Section); and with the Divisions of Plant Industry and Soils and the Department of Agriculture in Tasmania on a project at "Frodsley", to elucidate the effects of fertilizers, including potash, on the production of pastures there and on the health and growth of sheep.

(*a*) *Studies on Microbial Metabolism* (Animal Health Laboratory, Melbourne).—Work has been continued on the nutritional requirements of the causal organism of pleuropneumonia of cattle, *Asterococcus mycoides,* which which can be grown only in a complex basal medium which has disadvantages in vaccine production. Experimentally, serum has been found to be replaceable by a heat-stable serum-protein fraction, cholesterol and "Tween 80" in balanced proportions, when the tonicity is adequately adjusted. It has been shown also that the organism requires some nucleic acid fragment or fragments for growth, and particular attention is being paid to nucleic acids in the cultivation of this and related pleuropneumonia-like organisms (P.P.L.O.) which are becoming increasingly important in the field of animal pathology. The role that oxygen plays is also being studied.

(*b*) *Physiological Genetics* (University of Adelaide).—The discovery that the absorption of sugar from the medium, by non-growing cells of *Neurospora crassa,* can inhibit growth of normal cells has to led to a hypothesis regarding carcinogenesis which is being tested on mice. In addition to suppression of cells of one type by those of another, the type of selective medium used to detect mutated cells and the number of dead cells present have both been shown to be sources of error not controlled in mutation experiments so far carried out.

Work on electron microscopy has been started successfully. The object is to study the minute structure of chromosomes. At this stage, the problem is to prepare orientated chromosome sections.

(*c*) *Studies in Population Genetics* (Poultry Research Centre).—Analysis of the part-annual records of the F_7 generation of pullets at the Poultry Research Centre confirmed most of the findings reported last year—

(i) The control flock of White Leghorns propagated without selection was again used as a base line from which to assess the performance of other flocks.

(ii) Mass selection based on individual egg records improved egg production, but at a lower and more erratic rate than family selection did. This mating group will not be continued.

(iii) Mass selection based on either excellent or inferior body conformation had no effect on the level of egg production. This group will not be continued.

(iv) The flock of White Leghorns bred by combined family and individual selection continued to make steady progress at the rate of about five eggs per year.

(v) The flock of White Leghorns propagated according to the late Dr. Hagedoorn's ideas, by mating sons of progeny tested sires to all of their half-sisters, showed at an increasing degree the deleterious effect of continuous half-sib matings, which lead in seven generations to a coefficient of inbreeding of 55 per cent. Egg production increased at a slower rate than in the family-selected outbred production flock, hatchability and chick viability were depressed, and variability was not decreased. Reproductive fitness of this flock was lowered to such a degree that it becomes increasingly difficult to maintain the size of this closed flock.

(vi) The inbred strains of White Leghorns reached a coefficient of inbreeding of 60-72 per cent. Although in some cases fertility, and in most instances, hatchability, chick viability, and egg production were adversely affected, a few families behaved differently. Not sufficient evidence is yet available to explain this observation. Strain crosses were made for the first time to obtain heterosis.

(vii) A line was started, in which males of one breed are selected according to the offspring they produce when crossed to a second breed. Leghorns and Australorps were chosen for this work. This method of selection is termed reciprocal recurrent selection.

An F_2 generation from White Leghorn and Australorp crossbreds was produced to permit further studies on the causes underlying heterosis.

Studies on the characters of heritability of egg production in the Werribee flock of White Leghorn pullets during the first three-four years of selection resulted in the following estimates:—25-30 per cent. for annual production, 31-33 per cent. for egg production to 72 weeks of age, and 32-33 per cent. for part-winter period up to 31st May.

(*d*) *Avian Physiology* (Poultry Research Centre).—A study has been started in which the effect of high and low protein diets on the egg production of purebred and crossbred fowls will be compared. This is part of the investigation into heterosis.

The research findings of this Centre on the transport of fowl sperm in the oviduct, as reported last year, have suggested new techniques for inseminating with fowl semen. A number of semen samples are now being stored under deep frozen conditions so that these methods can be tested under field conditions.

Semen quality tests carried out during the breeding season showed that poor fertility obtained with 0.2 c.cm. of three times diluted semen in most of the highly inbred strains was correlated with sperm density values below 1.8 x 10^9 per c.cm. undiluted semen.

(*e*) *Other Observations on Poultry* (Poultry Research Centre).—The analysis of the post-mortem results from four years of pullet mortality in the flocks of this Centre confirmed leucosis as the main cause of death. It was responsible for a 7.5 per cent. mortality of the flock as a whole, and for 35 per cent. of the deaths in 2,371 pullets which died.

Plans have been completed for an experiment during the hatching season of 1956, to investigate the effect of brooding chickens in proximity to adult birds, on the incidence of leucosis in later life.

(*f*) *Comparative Biochemistry of Copper* (Department of Agriculture, Perth).—A paper on "The copper content of the liver and blood of some vertebrates" has been recently published. Therein, it was suggested that, in species with relatively high normal liver copper levels (the sheep, the duck, the frog, and certain fish), there might be some inability to regulate storage of copper, when compared with the majority of other species studied. This theory has now been tested with groups of ducks and domestic fowls receiving three levels of copper in the diet for varying periods, from three weeks of age up to fifteen weeks of age. Although there were differences in liver copper levels between the species, ducks, contrary to expectation, showed definite evidence of ability to regulate copper storage at higher levels of intake.

(*g*) *Kimberley Horse Disease* (Animal Health Laboratory, Melbourne).—In conjunction with other workers, especially those of the Northern Territory and Western Australia, the investigation of this disease has been continued. With the incrimination of *Crotalaria retusa* as the poisonous plant responsible for this disease in the chief areas affected, measures for minimizing the incidence of the disease can now be applied. At this laboratory, these studies are being integrated with others on the pathological effects of plants poisonous to domestic animals, especially those containing hepatotoxic alkaloids; co-operative work in this field is also pursued with the Division of Industrial Chemistry.

12. ANIMAL GENETICS.

(Animal Genetics Section.)

The Animal Genetics Section aims to investigate the possibility of applying genetics to animal breeding and allied fields and to train students interested in the subject.

One M.Sc. student finishes his training this year. Six students are undertaking post-graduate work with the Section and one is specializing in third year Genetics. Two lecture courses are being given, one of 30 lectures to second-year science students on genetics and one of about 50 lectures to honours and post-graduate students on experimental biology. A teaching film demonstrating the main features of meiosis was sold successfully in the United States, and a companion film on mitosis is under way. The laboratories being built in the Zoology Department of the Sydney University are nearing completion and should be occupied early in the financial year.

(*a*) *Genes and Chromosomes.*—Arrangements have been made to collect a small number of echidna and platypuses to continue studies on the amount of nucleic acid per nucleus in mammals other than eutherian mammals. Experiments on crossing-over in *Drosophila melanogaster* have been continued. Preliminary results suggest that the age of a female has a more profound effect on coincidence than it does on crossing-over, and adds further to the body of data showing these to be to some extent under independent control. No positive correlation has been found between the effect of modifiers on the number of bristles on the scutellum and the number of chaetae on the abdomen in studies of the expression of the scute gene in *D. melanogaster*. Since the scute gene reduces the number of chaetae on the abdomen by half, this finding is somewhat unexpected. An experiment to measure the correlation between scutella bristles and abdominal chaetae is nearly completed; correlation if present appears to be negative. Work on the effect of cold on mutation rate, which has been taken as far as is wished to take it for the time being, has been followed by work on the effect of heat treatment on mutation rate. Treating males with near-lethal temperature appears to produce bunches of mutated sperm, sometimes as high as 20 per cent. of all sperm produced by the treated male.

(*b*) *Myxomatosis.*—The animal house at Prospect is nearing its estimated maximum output of 2,000 rabbits a year. Selection of rabbits for resistance to the KM13 virus is in the third generation. A marked change in the rabbit's ability to acquire immunity has been produced during this time. The problems now being investigated are, firstly, to determine in what way resistant differ from non-resistant rabbits, and, secondly, to show whether response to myxoma virus is correlated with response to other pox viruses. For this purpose the selection lines will be continued and their response to killed virus measured and compared to the response of unselected rabbits. It is possible that the difference between the lines lies in speed or magnitude of response or both, or even that resistance is not connected with antibody production at all. Large supplies of virus are required for this work; as present methods of harvesting yield only 1/10 mg. from a rabbit, improved methods must be found. In order to measure the inactivation of virus by antibody quantitatively the biological method of assaying virus is being extended. The fertility of rabbits recovering from myxomatosis has been shown to be closely related to the severity of the attack.

(*c*) *Serology.*—Factors affecting the amount of antibody produced by an animal when challenged are still being studied. The low heritability of response of mice to injection of sheep red cells is confirmed. The response of mice to antigen is more sensitive to environmental factors as the mouse becomes older. It is affected by bleeding; very severe bleeding reduces antibody production, slightly less severe bleeding increases it, anything less than severe bleeding has no effect at all. A line of mice selected for high and low response to oestrogen has shown differences in response to injection of sheep red cells depending on the route of injection used, which suggests that the lines differ in the rate at which they absorb antigen from different sites of injection. Studies of anaphylaxis in mice have shown a dependence on dose which is not yet clearly understood. The problem is also being investigated by use of skin grafting in mice. Attempts are being made to mask the homograft reaction by pretreatments of various kinds. It has been found that homografts between animals related by six generations of backcrossing will take at the second grafting though not at the first.

(*d*) *Mice.*—Experiments on selection and variability continue. The lines selected for sensitivity to oestrogen given by the intravaginal route have reached the eleventh generation and continue to respond to selection. Four lines have been commenced for selecting for response to oestrogen given subcutaneously. The inbred lines which were subdivided into five sublines all have reached a point where variation between sublines of an inbred line can be measured. The tabby gene is being used to compare selection in a line where the character (vibrissa number) is variable to selection with one which is not. Variation of vibrissa number though present in some stocks of normal mice is much less than in tabby mice. Studies on skin and hair in mice have shown the importance of mast cells to pigmentation of hair. Work has been begun using X-rays to relate the bleaching effect of X-rays to events in the skin. Mast cells appear to be affected by X-radiation. Use of X-rays has produced phenocopies, but so far none of the kind sought, i.e., affecting skin and hair growth.

VI. NUTRITION.

1. GENERAL.

As an exact knowledge of the nutritional physiology of ruminant animals is of primary importance to the solution of problems imposed by climate and terrain on pastoral industry in Australia, the Organization, early in its development, formed a research Division to seek by experiment new knowledge of how sheep and cattle deal with their fodder, and to determine what nutritional elements are required to maintain flocks and herds in normal health and production. The research in this field has been confined mainly to the nutritional biochemistry of the sheep.

Division of Biochemistry and General Nutrition.—The Division has devoted its attention mainly to studies of the nutritional factors which govern wool production, and particular attention has been given to the capacity of various pastures to provide the sheep's requirements of essential nutritional elements. In general the course of the study has been to establish fundamental knowledge and then apply it. Extension of knowledge gained by intensive research in the laboratory to practice in the pastoral industry has resulted in spectacular economic returns.

Successes arising from this approach have been mentioned in previous Reports; new ones continue regularly to appear. One instance which, during the past year, has arisen from investigations that apparently had no immediate practical significance may be mentioned here as an example of the fruitfulness of this approach.

During the course of a study of the movements of the fore-stomachs of the sheep, a chance observation revealed the fact that when swallowed, a heavy object—a bullet for instance—remains either at the bottom of the rumen or makes its way to the reticulum, a contiguous organ whose contents periodically mix with those of the rumen. Further investigation of this phenomenon provided a clue to a means by which an adequate cobalt concentration within the rumen contents may be maintained indefinitely, and at very little cost, by dosing individual animals with "heavy" pills from which cobalt will dissolve at the rate necessary to provide the very minute quantity required to ensure protection against cobalt deficiency or against phalaris staggers. In this way the considerable cost and inconvenience involved in the frequent drenching of flocks and herds or in the application of cobalt in manurial dressings on the pastures can be overcome. A new principle which may have many other applications in husbandry practice has thus been established. This will be discussed in further detail in other sections of this Report.

Some of the other current investigations are described in this Chapter and further detailed references are made under Chapter III., Section 11, and Chapter VII., Sections 2-9.

2. NUTRITION AND WOOL PRODUCTION.

(Division of Biochemistry and General Nutrition.)

Summaries of researches that have led to the present understanding of the main relationships between nutrition and wool production have been presented in previous Reports. Current investigations aim at estimating, under various feeding conditions, the extent of the synthesis of methionine and cystine that is effected by microorganisms in the rumen; and in this connexion particular attention is being given to the extent of conversion of fodder proteins to microbial proteins by the rumen flora and fauna.

Further studies are being made on the influence of copper-containing enzymes on the processes of keratinization and pigmentation of wool fibres. Details of these investigations appear under various headings in Chapter VII.

3. STUDIES OF THE METABOLIC PROCESSES OF SHEEP.

(Division of Biochemistry and General Nutrition.)

Knowledge of the intermediary metabolism of fatty acids by the sheep has been very considerably extended during the year by a series of experimental studies that were undertaken primarily to throw some light on the metabolic lesion that gives rise to the syndrome of vitamin B_{12} deficiency which ensues in ruminant animals when the amount of cobalt in their fodder remains for a considerable period less than the critical concentration necessary to maintain a normal microflora within the paunch.

Further studies of the sugar metabolism of the sheep, which have extended knowledge of this aspect of ruminant physiology, have been made and have thrown light on the underlying mechanisms involved in the disordered sugar metabolism that gives rise to diabetes.

These researches are referred to in more detail in Chapter VII.

4. ENERGY METABOLISM OF THE SHEEP.

(Division of Biochemistry and General Nutrition.)

The studies of the thermodynamics of the overall energy transactions of the sheep have been continued. The interplay of energy metabolism and protein metabolism is receiving a special attention. To facilitate investigations of the rate of protein turnover a mass spectograph especially suitable for the determination of $^{14}N/^{15}N$ ratios has been installed at the laboratory.

Various aspects of the application of energy metabolism to other problems of sheep nutrition are referred to in Chapter VII.

5. MICROBIOLOGICAL PROCESSES OF RUMINATION.

(Division of Biochemistry and General Nutrition.)

Previous Reports from this Division have stressed the fact that the nutritional welfare of a ruminant animal is determined by the microorganisms that inhabit its paunch. As little is yet known of the factors that are essential for the nutrition of these microbes, a series of investigations was begun some time ago to throw more light on this important aspect of ruminant nutrition. The results of experiments during the period under review have stressed further the fact that the composition of the ingesta affects remarkably the nature of the mixed population of microorganisms that inhabit the rumen. These investigations have demonstrated, in particular, the very striking dependence of particular classes of bacteria on heavy metals—cobalt for instance. This and other aspects of current researches are referred to in various sections of Chapter VII.

6. SALT TOLERANCE OF SHEEP AND POTABILITY OF STOCK WATERS.

(Division of Biochemistry and General Nutrition.)

The lacunae in our knowledge of the tolerance of Merino sheep to the mineral salts that occur in bore waters, and the importance of information that will allow those engaged in pastoral industry a better means of assessing the potability of stock waters, have been stressed in previous Reports. The new knowledge gained during the past year from a series of experiments which aims to determine *inter alia* the greatest concentration of these salts that sheep can tolerate in their drinking water is discussed in Chapter VII., Section 9.

7. CARBOHYDRATES AND STEREOCHEMISTRY.

(Division of Biochemistry and General Nutrition.)

A better understanding of the nature of the defects in metabolism which supervene on nutritional deficiencies rests heavily on an extension of knowledge of the enzyme reactions that are the basis of living processes; and this, in turn, rests to a considerable degree upon stereochemical knowledge. For this reason a small Section has been established in this Division to conduct research in stereochemistry, primarily in the field of carbohydrate chemistry.

The work on the separation of carbohydrates by paper ionophoresis, mentioned in the previous Report, has been continued. Data have been obtained for the ionophoretic migration of all common sugars and sugar alcohols, and representative simple glycols, in several electrolytes. Difficulties of detection of carbohydrates on the paper strips containing electrolytes have been successfully solved by modifying established procedures, and by developing new methods. A preliminary account of the above work has been submitted for publication.

The mechanism of the transport of carbohydrates during paper ionophoresis is now being examined. As the results of the initial experiments cannot be completely reconciled with currently accepted views about the reaction between boric acid and polyhydroxy compounds, new hypotheses have been formed and are now being tested experimentally.

Concurrently with the paper ionophoresis, work is being continued on the formation of cyclic acetals of carbohydrates, as the same fundamental stereochemical principles are involved in the two reactions. Some results that are both useful and theoretically important have been obtained during the preparation of cyclic acetals from *cyclo*hexanone. Present indications are that the studies of acetal formation and of complexes with boric acid are yielding results that will be important also in fields of knowledge other than that of carbohydrate chemistry.

8. MINOR ELEMENT DEFICIENCIES IN ANIMALS.

(Division of Biochemistry and General Nutrition.)

(*a*) *General.*—Studies of the nutritional importance of traces of heavy metals have been for a number of years one of the central activities of the Division, and the economic consequences that have supervened on the application of knowledge arising from these studies have been dramatic. Many of them have been conducted with experimental flocks in the field under conditions which prevail in station practice and many have been conducted with experimental sheep confined in pens and in metabolism cages. Solution of some of the problems is facilitated by employing small experimental animals under laboratory conditions.

(*b*) *Copper Deficiency in the Rat.*—Previous Reports have outlined the results of the series of studies that have demonstrated the effects that molybdate ions in conjunction with sulphate and sulphide ions have on the copper metabolism of the sheep, and have remarked upon the important consequences of variations in the relative concentrations of these elements in the pastures of large tracts of Australian grazing country.

Certain fundamental differences in the reactions of ruminants (sheep) and rodents (e.g. rat) to these nutritional variables that have been revealed have been mentioned in these Reports. Further studies of the underlying mechanisms responsible for these differences have extended our knowledge of this phenomenon. They have provided elegant proof that copper enters into a number of different physiological processes and have shown that, in the competition among these processes when the overall supply of copper to the animal is inadequate, the catalytic reactions responsible for oxidation of thiol groups suffer first. The first apparent symptom of copper deficiency that appears in the sheep is the lesion in the wool fleece.

During the year under review a comprehensive study has been made of the rat's capacity to deal with a relatively large intake of sulphide. Soluble sulphides, Na_2S for instance, were found to be surprisingly well tolerated, but if the intake is high the animal's copper status becomes reduced and the symptoms that make up the progressive syndrome of copper deficiency appear.

In addition, experiments were conducted to illuminate further the effects that the ingestion of molybdenum and sulphate has on the distribution of copper-containing complexes in the blood and tissues, and on the chemical nature of copper complexes stored in the liver.

(*c*) *Copper Deficiency in the Sheep.*—The long-term experiments with sheep confined in pens on copper-deficient rations comprised essentially of wheaten chaff and wheat gluten have been concluded. These experiments have clarified many aspects of copper metabolism and especially have illuminated the mechanisms that control the assimilation, storage, and excretion of copper by the grazing sheep. The results are being prepared for publication. Many of these animals have been retained for special studies of various aspects of copper deficiency.

The copper-catalysed physiological process through which the black pigment, melanin, is produced has been the subject of a series of studies during the year.

Experimental studies of other aspects of the copper metabolism of sheep are reported in Chapter VII.

(*d*) *Zinc Deficiency in the Rat.*—Chemical techniques that render possible the production of rations adequate in all respects other than their capacity to provide the amount of zinc necessary to fulfil the requirements of the rat have been mentioned in previous Reports, and the behaviour of experimental animals when confined to such diets has been remarked upon. These studies have been continued to provide further information about the metabolism and function of zinc in the animal tissues. ^{65}Zn of high specific activity was used as a tracer to determine the rate of uptake of zinc by experimental animals that had been rendered zinc deficient, and to establish the distribution and location of zinc in their tissues. Following the observation that nitrogen metabolism is seriously impaired by zinc deficiency, a study of nitrogen retention and turnover is being made with ^{15}N-labelled glycine. Concurrent with these studies a comprehensive investigation is being made of the respective rates at which energy is dissipated by zinc-deficient rats and paired normal controls under standard conditions.

9. VITAMIN B_{12} AND COBALT METABOLISM.

(Division of Biochemistry and General Nutrition.)

(*a*) *General.*—Previous Reports have mentioned the studies that proved the untoward effects of cobalt deficiency in the ruminant to be due to a deficiency of the cobalt-containing accessory food factor vitamin B_{12}. Further experiments conducted during the past year have shown conclusively that the microorganisms responsible for the production of vitamin B_{12} in the rumen are critically dependent upon the cobalt concentration of the rumen contents, and that when this falls below a limiting amount there is a very manifest change in the associative growth of microflora. A precipitate fall in the vitamin B_{12} production accompanies this change but the fermentative processes which convert to simple fatty acids the complex, insoluble carbohydrates of the fodder remain unaffected. The microorganisms that flourish when the cobalt concentration is adequate have essentially a different metabolism and are apparently capable of dealing with certain substances that, if absorbed unaltered, are toxic to the animal. This latter important aspect of the function of cobalt in ruminant nutrition will be considered in a later section in which the malady phalaris staggers is discussed.

(*b*) *Microbiological Estimation of Vitamin B_{12} and Folic Acid.*—The progressive fall in the concentration of vitamin B_{12} in the liver which supervenes when sheep are confined to cobalt-deficient rations has been studied further, and its relationship with the vitamin B_{12} concentration of the blood plasma has been established so as to render certain the diagnosis of cobalt deficiency. Deficency symptoms appear when the vitamin B_{12}-activity in the liver falls below 0.1 μg vitamin B_{12}/g. wet weight. The corresponding concentration in the plasma is then between 0.2 and 0.3 mμg. vitamin B_{12}/ml.

Suitable microbiological methods for the estimation of folic acid have been developed, and preliminary observations indicate that the concentration of folic acid in the liver is closely related to the vitamin B_{12} status of the animal.

(*c*) *Vitamin B_{12}, Folic Acid, and Haemopoiesis.*—Further studies have been made of the anaemia that is associated with cobalt (vitamin B_{12}) deficiency in the sheep, and observations on the relative effects of folic acid and of vitamin B_{12} on the macrocytic anaemia which occasionally supervenes on cobalt deficiency in the sheep have been extended. The findings stress further the close functional relationship between folic acid and vitamin B_{12}.

The studies of the prophyrin metabolism mentioned in the last Report have been completed and the results published.

(*d*) *Intermediary Metabolism of Vitamin B_{12}-deficient Sheep.*—A series of studies have been begun which aim to reveal the metabolic lesion responsible for the greatly reduced capacity of the vitamin B_{12}-deficient ruminant's tissues to deal with the foodstuffs absorbed from the intestine. There is unequivocal evidence that when the cobalt concentration is abnormally low, the changes in the rumen microflora have no influence on the overall digestibility of the fodder, nor do they effect materially the nature of the end-products arising from bacterial dissimilation of the fodder within the alimentary canal. Some of the findings from this study of the intermediary metabolism of vitamin B_{12}-deficient sheep are mentioned in Chapter VII.

10. PLANT NUTRITION.

(Division of Biochemistry and General Nutrition.)

The programme of studies of the function of zinc in the pasture plants has been continued. A brief resumé of the findings during the period under review appears in Chapter III., Section 11.

11. FIELD STATIONS.

(Division of Biochemistry and General Nutrition.)

Semi-intensive studies of cobalt and vitamin B_{12} deficiencies in sheep and of the interplay of copper and molybdenum in the nutrition of ruminants have been carried out at the Division's block of pens situated at the Waite Institute.

The experiments on salt tolerance, on protein supplements for sheep, and on the effects of chronic fluorosis, which are described elsewhere in this Report, have been conducted at the Division's central field station, Glenthorne, a property of 600 acres situated 11 miles from the main laboratories. This station now carries 1,400 strong-wooled (Anama) Merinos and a nucleus flock of fine-wooled (Havilah) Merinos. Development of this station is proceeding as labour and materials become available.

Several other field stations are situated elsewhere on terrain where deficiencies occur. Field investigations of phalaris staggers and of the deficiencies of copper and cobalt in sheep are proceeding at Brecon and at Robe respectively.

12. PHALARIS STAGGERS.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter VII., Section 7.

13. UREA AND NITROGENOUS COMPOUNDS AS A SOURCE OF NITROGEN FOR RUMEN MICROORGANISMS.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter V., Section 8.

VII. SHEEP.

1. GENERAL.

The sheep holds a unique position in the Australian economy. Wool is our major export, and primary products from the sheep industry such as wool, lamb, mutton, and hides comprise up to 45 per cent. of all Australian rural production. The sheep, too, allows of the use of vast areas of marginal land which it has not so far been practicable to use for other purposes. With a sheep population of over 125,000,000 Australia produces about one-quarter of the world's wool and about twice as much as any other country. More than one-half of the world's production of fine wool comes from our dry inland areas. Thus Australia has a vital interest in ensuring that wool can withstand the competition from artificial fibres. The remarkable success of the latter has been due in the main to the clear understanding, arising from research, of the physical and chemical properties of the new fibres. Moreover, the chemical industry established to produce them is planned as a co-ordinated and organized unit, which ensures maximum efficiency and minimum wastage at all stages.

It is a major aim of the Organizations integrated programme of research in aid of the wool industry to investigate every phase of sheep and wool production: soils, pastures and nutrition, genetics, animal husbandry, wool processing, textile manufacture, and the exploitation of by-products. The Organization has been given responsibility for carrying out this extensive programme under the provisions of the *Wool Use Promotion Act* 1945. The Government has set aside funds earmarked for this purpose amounting to almost £400,000 per annum in a Wool Research Trust Account. Further moneys for capital expenditure are available from interest on the £7,000,000 of the Wool Industry Fund.

Soil fertility is obviously of prime importance and outstanding results have been achieved in improving soil infertility arising from minor element deficiencies. On the plant side, too, special emphasis has been placed on pasture improvement and weed control. The work of the Organization on soils, pastures, and related matters affecting the pastoral industry is carried out by the Division of Soils and the Division of Plant Industry (*see* Chapters II. and III.).

Work on the sheep itself has been undertaken within the Division of Animal Health and Production (*see* Sections 10-20 and 22 of this Chapter) and the Division of Biochemistry and General Nutrition (*see* Sections 2-9 of this Chapter). The Division of Mathematical Statistics is closely associated with the breeding investigations. The Animal Genetics Section's work on sheep breeding is described in Section 15 of this Chapter, and that of the Division of Entomology on the sheep blowfly in Section 21 of this Chapter.

The Organization's work in the investigation of wool processing and wool textile problems is undertaken at the Wool Textile Research Laboratories and the Division of Industrial Chemistry (*see* Chapter XVI.).

2. NUTRITION AND WOOL PRODUCTION.

(Division of Biochemistry and General Nutrition.)

The general background of these studies has been discussed in previous Reports. The greater part of the investigations of the Division of Biochemistry and General Nutrition is devoted to the solution of problems which bear more or less directly upon this particular aspect of the great pastoral industry. Some of these have been discussed in Chapter VI.

During the period under review the investigations have been directed mainly to the influence of copper on the keratinization process within the follicles. Experimental studies have also been made to illuminate further the interrelationships between energy metabolism, protein turnover, and the rate of wool production. This latter series of experiments is essentially a long-term research which aims to establish *inter alia* the relative levels of protein and utilizable energy which will ensure the most efficient utilization of protein for wool production by high-producing merino sheep. These experiments are mentioned elsewhere under Section 4 of this Chapter.

3. MICROBIOLOGICAL PROCESSES OF RUMINATION.

(Division of Biochemistry and General Nutrition.)

Further experimental studies of the fate of nitrogenous compounds in the fore-stomachs of the sheep have confirmed the preliminary finding that the proportion of the dietary nitrogen reaching the duodenum may vary widely according to the nature of the diet. With a relatively high level of nitrogen in the ration, as in lucerne hay, the amount reaching the duodenum may be equivalent to less than 50 per cent. of the quantity fed, but on a diet containing only 1 per cent. or less of nitrogen, e.g. wheaten hay, the amount may actually be greater than that fed. The ratios of nitrogen to lignin in the various compartments of the fore-stomachs, when compared with each other and with the ratio in the diet, indicated that in sheep fed on lucerne hay the nitrogen lost from the ingested foodstuffs before it reached the duodenum was lost by absorption through the rumen wall. In sheep fed on low-nitrogen diets it is probable that such losses are very small and that the ratio of nitrogen to lignin in the stomach contents can be increased significantly by the influx of nitrogen into the alimentary tract through saliva, blood, or gastric juice.

The investigation of microbial protein from the rumen has been extended and now includes amino acid analyses of preparations of protozoa and bacteria from sheep fed on wheaten hay, wheaten hay + oats + urea, lucerne hay, and pasture. The bacterial protein exhibited a very uniform composition, the protozoal protein rather less regularity; but both were very similar to pasture protein. The main differences were that the bacterial protein was somewhat richer in lysine and methionine, and poorer in leucine and histidine than pasture protein. The more variable protozoal protein was consistently richer in four of the "essential" amino acids, leucine, isoleucine, phenylalanine, and lysine. These findings suggest that for at least a fairly wide range of types of ration the nutritive value of the microbial protein of the rumen is almost constant and that only a very extensive conversion of plant to microbial protein would lead to a significant change in the proportions of amino acids finally made available to the host animal. Such changes would be maximal if the conversion were to protozoal rather than bacterial protein.

4. ENERGY METABOLISM OF SHEEP.

(Division of Biochemistry and General Nutrition.)

During the year the calorimetric chambers have been employed in a number of studies of the energy transactions of sheep under different feeding conditions, the main investigation being that mentioned under Section 2 of this Chapter.

5. CARBOHYDRATE METABOLISM OF THE SHEEP.

(Division of Biochemistry and General Nutrition.)

Investigations mentioned in the previous Report have been continued and additional evidence has been obtained to indicate important differences between the metabolic channels of young and of adult sheep. Detailed knowledge of intermediary metabolism of normal sheep is essential for a better understanding of many nutritional disorders encountered in grazing herds and flocks.

(*a*) *Diabetic Sheep and Lambs.*—Sheep and lambs rendered diabetic by surgical removal of the pancreas are being employed in the study of certain aspects of carbohydrate and fat metabolism. Tolerance curves of acetate, propionate, and butyrate have been established for normal and diabetic sheep. Differences in the rate of removal of these substances from the blood stream after they have been injected indicate that the diabetic sheep's capacity to utilize these lower fatty acids is impaired. The implication that insulin plays a part in the utilization of the lower fatty acids, and the possible influence of other hormones by interaction, are being investigated further.

(*b*) *The Influence of Fodder on the Utilization of Lower Fatty Acids.*—Implications arising from the fact that toxicity of fluoroacetate is influenced by the nature of the diet have been mentioned in previous Reports. This phenomenon has been studied further by examining the tolerance to acetate of sheep fed different types of fodder. Sheep tolerate fluoroacetate much better when they are fed on lucerne chaff or green pasture than when confined to rations comprised of wheaten chaff or of dry pasture.

(*c*) *Acetylation in Sheep and Lambs.*—The role of acetylation in relation to the differences between the ability of young lambs and adult sheep to metabolize carbohydrate is being studied, and the gradual loss of the young lambs' ability to acetylate sulphanilamide as maturity is approached has been demonstrated.

6. MINOR ELEMENTS IN THE NUTRITION OF SHEEP.

(Division of Biochemistry and General Nutrition.)

(*a*) *Cobalt Deficiency in Ruminants.*—A sheep must ingest approximately 100 μg cobalt each day to provide for the elaboration of sufficient vitamin B_{12} to satisfy its nutritional requirements for this essential cobalt-containing vitamin.

Ruminants grazing in regions where there is insufficient cobalt in the pastures to provide this essential minimal requirement of cobalt suffer the serious disabilities of cobalt deficiency, unless their cobalt intake is adequately supplemented, and these supplements must be given *per os* if they are to be effective. Thus, in practice, extra cobalt is provided to flocks on deficient terrain either in the form of drenches, which must be administered frequently, or as a constituent of salt licks. In certain circumstances the costly practice of raising the cobalt status of the pastures by the application of manurial dressings of suitable cobalt compounds has been adopted. Drenching is laborious, licks are an uncertain medium, and the costs of top-dressing pastures with cobalt are usually prohibitive, as, more often than not, the effects are ephemeral. A simple, effective, and inexpensive means of maintaining the necessary concentration of cobalt within the rumen would thus greatly facilitate husbandry practice in deficient areas.

(*b*) *A New and Simple Means of Providing a Cobalt Supplement to Sheep.*—A novel and very promising means of maintaining the desirable concentration of cobalt within the rumen was indicated by a chance observation that a dense object—a bullet for instance—will, if swallowed by sheep, remain either within the rumen or in the contiguous fore-stomach, the reticulum, the contents of which mix freely with the contents of the rumen. Clearly a "pill" of suitable size and density from which cobalt would dissolve very slowly—i.e. between 0.1 and 1.0 mg. cobalt/day—would provide a means of overcoming the expensive and irksome husbandry practices entailed in the frequent drenching that is necessary to combat the untoward effects when the pastures are short of cobalt.

Considerable attention has been devoted to the production of suitable "pills". Small cylinders comprised of pure cobalt or of certain cobalt alloys give up, by corrosion, the required amount of cobalt when immersed in distilled water or dilute salt solutions, and they remained without exception either in the rumen or in the reticulum, but on trial they were ineffective as they would not corrode in the highly reducing milieu of the rumen contents. Cobalt silicates in the form of glass marbles were tried. Cobalt is removed freely from these by base-exchange in the rumen contents but this approach was abandoned because the objects were hardly dense enough to remain always in the rumen. The most feasible material so far investigated is a mixture of cobalt oxide and china clay. The hard, porous cylinders that result when this mixture is moulded and baked at high temperatures are sufficiently dense to remain in the fore-stomachs, and cobalt dissolves from them into the rumen contents slowly but at a sufficient rate to ensure a concentration adequate for the growth of the microflora responsible for the production of vitamin B_{12}.

Further extensive testing under a variety of field conditions is desirable, and is being arranged, but at this juncture there can be little doubt that these dense, cobalt-containing pills will prove to be a feasible, inexpensive, and simple means of ensuring that the cobalt concentration of the rumen contents is maintained continually at a level necessary for complete protection of sheep against vitamin B_{12} deficiency, and phalaris staggers (*see* Section 7). One dosing should protect for many months, probably for some years, and there is reason to believe that suitable pills may be developed that will remain in the rumen during the whole life of the animal and continue throughout to provide the very small amount of cobalt that is so essential.

(*c*) *Copper Deficiency in Sheep.*—Previous Reports have mentioned experimental studies of the effects of molybdenum and sulphate on the copper metabolism of sheep. These investigations have been extended with experimental flocks confined to the copper-deficient pastures at Robe, where the sheep were depastured without copper supplementation until they exhibited all of the signs of advanced copper deficiency: i.e. until the wool fleece showed the typical copper deficiency lesion, the concentration of copper in the liver and the blood had fallen to very low levels, anaemia had developed, and haemosiderosis of the liver was advanced.

When in this state the animals were mated and the appropriate treatments with copper, molybdenum, and sulphate were commenced.

The concentration of copper in the blood of all animals that received copper supplements rose sharply; molybdenum supplements in addition to copper induced and maintained consistently greater rises. In the animals that received no copper supplements the blood copper level remained low, but in those copper-deficient ewes that received molybdenum the blood-copper concentration rose appreciably. The sulphate supplements had no effect on the blood copper levels.

The wool of all the sheep that received copper improved, although the deficiency lesion remained apparent in the fleeces of the animals that received molybdenum in addition to copper. The sheep that were not provided with copper supplements continued to grow steely wool, the character of which deteriorated further in the animals that received molybdenum. Sulphate had no apparent effect on the nature of the fleece.

Lambing was closely observed. Enzootic ataxia was apparent at birth in the lambs born to all the copper-deficient groups of ewes, except those that were treated with molybdenum; demyelination in these lambs was delayed but developed subsequently. Histological examination of the brains and cords from all these lambs is being carried out. The effects of the treatments on the concentration of copper and of iron in the liver of the ewes will be determined in further biopsy samples. This work is proceeding.

7. PHALARIS STAGGERS.

(Division of Biochemistry and General Nutrition.)

The cause and prevention of phalaris staggers in sheep confined to pastures in which the perennial grass *Phalaris tuberosa* predominates have been studied further at the experimental site near Keith. Experiments mentioned in previous reports proved that relatively large supplements of cobalt, administered once or twice each week, afforded complete protection from the malady. Experiments conducted during 1955 showed that as little as 0.05 mg. cobalt administered each morning and again each evening, was equally effective; there is no doubt that the prevention of the disease depends upon the maintenance of a minimal concentration of cobalt within the rumen.

It is probable that those rumen microorganisms that require cobalt and demand a relatively high concentration of cobalt if they are to flourish within the rumen contents are able to destroy neurotoxic substances present in the phalaris. Protection of ruminants against the untoward consequences of these toxic substances thus presents essentially the same problems as those entailed in protection of grazing flocks and herds against cobalt deficiency. The heavy cobalt pills referred to above will undoubtedly find ready application in areas where there is a hazard of phalaris staggers.

The application of 1 lb. cobalt sulphate acre to phalaris-dominant pasture has been shown to raise the cobalt concentration in the phalaris to a protective level for several months only, so this procedure is not recommended as a practical means of control. A further experiment in which cobalt sulphate has been applied at the rates of 2, 4, 8, 16, and 160 oz./acre has shown that the residual effect of even 2 oz./acre is sufficient to raise the cobalt concentration in the phalaris to a protective level (0.1 p.p.m.) for seven weeks but that only the greatest rate (160 oz./acre) maintains this concentration at more than 0.07 p.p.m. after fourteen weeks.

It is possible, therefore, that a relatively light dressing of cobalt sulphate applied annually at the break of the season in the autumn, might be sufficient to protect the grazing sheep during the critical period in early winter when the phalaris most commonly predominates. But these procedures will no doubt be superseded by the employment of heavy cobalt pills. These experiments are being continued.

A preliminary experiment has been started at the Falkiner Memorial Field Station, Deniliquin, in collaboration with officers of the Regional Pastoral Laboratory, to determine whether phalaris pastures there may be toxic also.

8. UREA AND NITROGENOUS COMPOUNDS AS A SOURCE OF NITROGEN FOR RUMEN MICROOGANISMS.

(Division of Biochemistry and General Nutrition.)

The possibility that urea or similar simple nitrogenous substances might find useful application as substitutes for protein supplements for ruminants has been discussed in previous Reports.

Experiments conducted with sheep in pens have shown that when the diet contains relatively large quantities of simple carbohydrates, an addition of urea stimulates the proliferation of microorganisms within the rumen with the result that useful quantities of protein are formed and wool production is enhanced.

The economic feasibility of supplementing flocks in this way will depend on the efficiency of utilization of the nitrogen source. Urea and another related compound, dicyandiamide, proved to be toxic and poorly utilized when fed under certain conditions as a constituent of supplementary mixtures.

A preliminary experiment was conducted to determine whether useful amounts of bacterial protein might be produced as the result of adding urea and molasses to green fodder which was being ensiled. Chemical analysis did not reveal any appreciable conversion of urea to protein, but a slight increase in wool production was observed in the few sheep fed for a very limited time on the urea-treated silage. A more detailed experiment will be needed to confirm this result.

Another attempt was made to produce bacterial protein from urea without subjecting the sheep to the hazards which might accompany the direct feeding of urea. Dry standing pasture was sprayed with a mixture of molasses and urea, but the treatment had no beneficial effect on body weight or wool production of the animals which grazed the pasture. This confirmed the conclusion tentatively drawn from a similar experiment in the previous year that such treatment is unlikely to be of benefit to sheep.

9. SALT TOLERANCE OF SHEEP AND POTABILITY OF STOCK WATERS.

(Division of Biochemistry and General Nutrition.)

The first of the series of long-term experiments to determine precisely the tolerance of sheep to saline waters, mentioned in the previous Report, has been completed.

The experiment which was continued for fifteen months indicated that water containing 2 per cent. of sodium chloride was definitely toxic for sheep on dry fodder, and that water containing 1.5 per cent. sodium chloride was slightly toxic; there was some evidence of adaptation to the high concentration. The sheep whose drinking water contained 1 per cent. sodium chloride suffered no untoward effects. None of the treatments had any effect on the electrolytes in the blood plasma of any of the sheep except those receiving 2 per cent. sodium chloride; the chloride concentration in the plasma of these animals was higher than that of any of the other groups.

The second experiment of the series has now been started. Sheep are being offered drinking water containing 1.3 per cent. sodium chloride or the same total electrolyte concentration with portion of the sodium chloride replaced by an equivalent amount of magnesium chloride, up to 0.5 per cent. The saline waters have been introduced gradually, and some difficulty has been experienced in inducing the sheep to accept the higher concentrations of magnesium chloride, a period of three months having been necessary in some cases. Indications so far are that 0.5 per cent. magnesium chloride is a toxic concentration.

The hazards of chronic fluorosis originating from the high fluoride concentration of certain artesian waters has been mentioned in previous Reports. The experimental studies of the toxicity of fluorides present in the drinking water of grazing sheep have been continued. The deterioration of the teeth of the sheep confined to water containing 20 p.p.m. F has again had an adverse effect on the animals, both body weight and wool production being affected, especially during the dry grazing conditions of late summer. Deaths during the whole period of the experiment among those receiving the high level of fluoride have been double those in the control group. However, for the fifth successive year there has been no adverse effect on reproduction; the numbers of lambs produced in the two groups have not been significantly different.

10. METABOLISM IN PREGNANT EWES.

(Division of Animal Health and Production.)

Pregnancy Toxaemia Investigations (Sheep Biology Laboratory).—Further studies have been made on naturally occurring cases of this disease, and on normal and fasted pregnant ewes. Attention has been focused on the levels of volatile fatty acids, ketones, glucose, and citric acid in the blood and tissues, and on the utilization of glucose, acetate, glycerol, and oxalacetic acid.

11. DROUGHT FEEDING AND ALLIED PROBLEMS.

(Division of Animal Health and Production.)

Drought feeding experiments with sheep have been continued by the staff of the McMaster Laboratory, in collaboration with the New South Wales Department of Agriculture at the Veterinary Research Station, Glenfield. Financial support was again provided by the New South Wales Graziers' Association from the Burdekin Bequest Fund.

(*a*) *Utilization of Low-quality Roughage by Merino Wethers.*—The experiments were designed to compare the value of supplements which provided additional energy intakes or additional protein to sheep with free access to oaten straw containing 3.4 per cent. crude protein. Supplements providing additional protein gave the better results, but the experiments were marred by heavy and continued rain. More exact studies will be made under laboratory conditions.

(*b*) *The Efficiency of Absorption and Utilization of Vitamin A Administered as the Oil, the Emulsion, or the Water-miscible Suspension.*—A carefully planned experiment revealed no difference in efficiency due to the form in which vitamin A was administered. Two weeks after treatment, vitamin A storage in the liver of previously deficient sheep was 12.9 per cent. of the quantity administered; after 22 weeks, it had fallen to 2.6 per cent. The mean plasma vitamin A level of weaners and ewes which developed night blindness was 9.4 ± 3.99 i.u. per ml.

12. TOXICITY OF LARGE RATIONS OF WHEAT.

(Division of Animal Health and Production.)

This investigation has been continued at the Animal Health Research Laboratory, Melbourne. Particular attention was given to the role of the spleen in relation to the characteristic haemoconcentration observed in this disease. Evidence was obtained that the spleen begins to discharge its stored red cells into the circulation about 6 hours after heavy wheat intake, and that the process is completed after a further 6 hours; up to this stage, during which a progressive decrease of plasma volume is occurring, blood volume may not increase; but, thereafter, as plasma volume continues to decrease, blood volume correspondingly falls. Attention was given also to the possible role of histamine in the condition; it was found that 300 μg histamine given intravenously produces extreme increases of red cell count, which are explained to only a very small extent by plasma water shifts; however, since histamine was without effect upon the perfused isolated spleen, it is assumed that the action in the intact animal is indirect, probably by release of catechol amines from the adrenal glands.

Work on the toxic factor in the non-dialysable fraction of the ruminal fluid of wheat-gorged sheep indicates that it withstood autoclaving at 10 lb. wt. for 20 minutes, and that its effect upon sheep was not inhibited by previous treatment with the antihistamine agent "Anthisan"; it was without effect upon the isolated guinea pig ileum, but caused the perfused sheep spleen to contract. Sheep could be rendered tolerant of it by several injections of sublethal amounts at short intervals, but since establishment of this state of tachyphylaxis had no observable effect upon the course of the illness after wheat gorging, no support was gained for the suggestion that absorption of this toxic material from the bowel might play a part in the condition. Several strains of amylolytic streptococci and lactobacilli were examined, but no non-dialysable toxic factor could be demonstrated in cultures.

Since the necessary operative procedures on sheep in this work are carried out under barbiturate ("Nembutal") anaesthesia, a study was made on the value of a barbiturate antagonist "Megimide", and of the respiratory stimulant "Daptazole", in curtailing anaesthesia and in saving the lives of sheep poisoned by excessive "Nembutal". This has been published.

13. INFERTILITY AND PHYSIOLOGY OF REPRODUCTION.

(Division of Animal Health and Production.)

(*a*) *Effect of Reversed Seasonal Lighting on Pregnancy in Merino Ewes* (University of Queensland).—The birth weight of Peppin strain Merino lambs was unaffected by exposing the pregnant ewes to summer level of lighting during a winter pregnancy.

(*b*) *Induction of Heat in Spayed Merino Ewes with Stilboestrol.*—Injections of 2 mg stilboestrol were continued at fortnightly intervals in 24 spayed Merino ewes. Initially, all ewes exhibited oestrus following injection. The response declined progressively, and, after the 13th consecutive injection, none responded. In continuation of the experiment, progesterone was given for several days before stilboestrol, at intervals of a fortnight; a high proportion of ewes responded immediately, and continued to do so on thirteen consecutive occasions. Observations are now being made to determine the sensitivity of Merino ewes to oestradiol benzoate when it is given alone, and when it is preceded by progesterone.

(*c*) *Mating and Its Outcome in the Field.*—Field work with five Merino flocks in the Western District of Victoria was brought to completion with data on weight changes in the lambs to twelve months of age. When feed dried off in the summer, the lambs and weaners on four of the five properties ceased to increase in weight, regardless of their age at the time. They did not commence to increase in weight again until green feed appeared in the autumn.

Observations on lambing were continued for a second year in sample groups from a Corriedale flock, in which half the ewes were joined in December and half in May. In each group, approximately the same proportion of lambs died before marking. Again, substantially better results were obtained from the May mating; the reason on this occasion being the lambing of a higher proportion of the ewes joined in May.

(*d*) *Effects of High Temperature on Pregnancy in Merino Ewes* (*University of Queensland*).—Although pregnancy is much more vulnerable to heat in Romney

Marsh than in Peppin strain Merino ewes, the latter suffered reduced birth weight of lambs when subjected to severe heat.

(*e*) *Double Joining of Ewes* (Regional Pastoral Laboratory, Armidale).—In some areas, graziers practice "double joining" of ewes when seasonal conditions are good and they are desirous of increasing flock numbers quickly. Ewes apparently not in lamb at the commencement of lambing are removed from the flock and remated.

To obtain information on the applicability of this husbandry practice to fine-wool Merino ewes under New England conditions, 100 dry ewes were mated between 26th September and 28th November, 1955. The first date is that of the normal commencement of lambing. Of the 100 ewes, 71 exhibited oestrus as indicated by marking by raddled rams. Forty-five ewes lambed, and one other ewe which died, subsequently to mating, was pregnant.

(*f*) *Physiology of the Foetal and Neonatal Lamb* (Sheep Biology Laboratory).—(i) *Effect of Fasting on Newborn Lambs.*—Lambs fasted from birth under standard conditions became comatose and developed characteristic symptoms within 16 to 65 hours. During fasting, blood sugar levels fell from about 80 mg./100 ml. to about 10 mg./100 ml. and rectal temperatures fell from about 103° F. to less than 95° F. Rate of excretion of nitrogen in the urine remained relatively constant at 30-40 mg. per hour. Livers of comatose lambs contained only traces of glycogen as compared with about 4 per cent. (g./100 g. wet weight) in lambs soon after birth. The magnitude of these changes was independent of birth weight or nutritional treatment of the ewe, but the time taken for them to occur depended more upon birth weight than upon the plane of nutrition, apart from its effect on birth weight.

(ii) *Temperature Regulation of Newborn Lambs.*—Lambs from ewes severely underfed during the last six weeks of pregnancy appeared to be less able to resist the cooling due to evaporation of fluid in the coat than did lambs from well-fed ewes.

(*g*) *Lactation in Merino Ewes* (Animal Health Laboratory, Melbourne).—At parturition, a thick, sticky, and opaque secretion was found in the udder in many ewes which had been on a low plane of nutrition for two, three, or six weeks. Within 24 hours, in most instances, this secretion changed to one of the type normally called "colostrum". The latter type of secretion was present in the udder at parturition in other ewes on a low plane of nutrition and in ewes which had been on an intermediate or a high plane of nutrition.

In further studies of hand milking, following the administration of posterior pituitary extract as a method of estimating milk yield in Merino ewes, it was found that estimates were unaffected by the time of day at which tests were made and that the administration of posterior pituitary extract early in lactation did not influence milk yield later.

(*h*) *Effect of Husbandry Practices on Lamb Mortality* (Regional Pastoral Laboratory, Armidale).—Observations on the incidence of lamb deaths between birth and marking, under different systems of lambing husbandry, were continued at Armidale in 1955. The systems compared were modified paddock lambing; station paddock lambing; unattended paddock lambing and later lambing "off shears" and "in wool". Details of these methods were given in reports for 1953 and 1954.

The results of three years' observations do not indicate the possibility of effecting any consistent reduction in lamb losses by the use of the modified paddock system of lambing husbandry.

Observations in the lambing "off shears" versus "in wool" experiment now extend over a period of four years. In three of these, lamb losses have been lower in the former group. However, over the four-year period, the total difference in lamb losses between these two methods of management was only 3 per cent., which is not significant.

14. Breeding and Genetical Studies.

(Division of Animal Health and Production.)

(*a*) *Inbred Flocks of Australian Merinos* (McMaster Field Station).—Inbreeding in this experiment appears to have had the following effects. No effect has been observed on density of fibre population. There appears to be a slight decline in fibre diameter at levels of inbreeding of 0.25 and over. There is an apparent increase in staple length at levels of inbreeding of 0.25 and above. Level of inbreeding has had no apparent effect on yield. Clean fleece weight declines with inbreeding; the decline is considerable at levels of 0.25 and above.

(*b*) *Hornedness in Sheep* ("Gilruth Plains", Cunnamulla).—Further test matings have been made so that a choice can be made between two hypotheses on the inheritance of hornedness and polledness in the Merino. A progress report on this work has been submitted for publication.

(*c*) *Strains of Merino Sheep in Several Environments.*—Analyses of data have been continued and have resulted in the tentative conclusion that strain x location interactions, though real, are too small and too variable from season to season to be important in deciding on the class of sheep to be run in a given area. An exception appears to be a real adaptation of the fine non-Peppin strain to the tableland environment at Armidale and its relatively poor fitness in the two western environments at Cunnamulla and Deniliquin.

(*d*) *Project AB1* (McMaster Laboratory and "Gilruth Plains", Cunnamulla).—The sheep-breeding project known as AB1 is in two parts. In one part, sires are selected in two ways: (i) on performance of half-sibs plus individual performance, and (ii) on individual performance alone. The criterion for selection is clean wool weight per head, with the restriction that an animal (ewe or ram) is rejected if its wrinkling score is above a predetermined value, or if its fibre diameter exceeds by more than one standard deviation the mean value of an unselected control group which is run with the selection groups.

With the high heritability estimates, which have been found for all characters associated with wool production, the prediction is that there will be very little difference between the two methods of sire selection. This has proved to be the case so far; there has been response to selection of the same order for both methods.

The second part of the trial consists of eight pairs of groups, in which selection is for high or low values of a single character. Three pairs of groups have been in existence for some time; in these, selection is for body weight, fibre number, and staple length. There has been marked response to selection in both directions. One interesting observation is that selection for fibre number has led to changes in both primary follicle count and the ratio of secondary to primary follicles. The importance of the two sources of change in relation to fleece weight will be further investigated.

Results on the first progeny in five new pairs of selection groups became available this year, the characters under selection being clean wool weight, wrinkling score, fibre diameter, wool weight per unit area, and per cent. clean-scoured yield. In all cases, there were marked responses to selection in either direction.

(*e*) *Relation between Wool Prices and the Characteristics of Wool* (Sheep Biology Laboratory).—Further analyses of the relation of prices paid for Merino wool to the various characteristics of wool have been carried out. These have confirmed the earlier conclusions that count (quality number) is of outstanding importance as a determinant of price, while colour and length have real, though smaller effects. Of the other attributes considered (diameter, crimps, handle, character, and soundness), all but soundness had appreciable direct relationships with price in the wools examined, when each was considered alone. However, when considered jointly with count, colour, and length, none of the above five traits had important joint effects on the prediction of price. Count, diameter, and crimps all have high correlations with each other, so that each should have an important effect on price, were the other two not considered.

(*f*) *The Assessment of Clean Scoured Yield by Subjective Methods.*—Clean fleece weight is an important criterion in selection programmes and a procedure which may be useful for its estimation by visual and tactile methods has been developed. This was tested by using observers with no previous experience in yield assessment. Ability to predict yield was generally good except in the case of a few unusual samples in which yield was considerably underestimated. The mean deviation of the yields assessed by each observer from the actual yields ranged from zero to –4.0 per cent. These mean differences have a standard deviation of about 4 per cent. A paper describing this work has been prepared for publication.

15. GENETICS OF SHEEP.

(Animal Genetics Section.)

Analysis of data collected by Dr. Carter has shown much about the detailed relationship of density of fibres and their diameter and genetic and environmental factors influencing both characters. By using covariance analyses much information relating to the ratio of primary and secondary fibres and the density of both has been revealed. At first sight genetic variation of primary density appeared slight and most variation in overall density of fibres could be attributed to variation in ratio. Covariance analysis reveals that primary density is variable, however, with quite a high heritability. Experiments have been started at Dickson Research Station to produce in the first instance an increase in ratio and later in density of primaries. When strains differing in these characters have been produced they will be examined to determine the relationship between follicle group size (ratio) and fleece production. A study of the spatial relationship in a developing follicle population is nearing completion. Studies of sheep mozaic for fleece type have shown so far that variation of follicle density and total cross-sectional area of fibre per unit area of skin are independent, that in areas of low density total wool production is greater. and that the relation of length to diameter is in some way connected with determination of follicle density and total cross-sectional area.

16. BIOLOGICAL STUDIES OF SKIN AND WOOL GROWTH.

(Division of Animal Health and Production.)

(*a*) *Endocrinology of Wool Growth* (Sheep Biology Laboratory).—(i) *Wool Growth and the Anterior Pituitary Gland.*—Work has continued on the identification and testing of the anterior pituitary hormones necessary for normal wool growth.

Several fractions of the hormones from the sheep pituitary gland have been labelled with radioactive iodine (^{131}I) in an attempt to improve the detection of these proteins on paper electrophoretic strips. Several radioactive bands have been detected by autoradiography, in addition to the bands produced by protein stains. The source of these extra bands is being investigated.

(ii) *Wool Growth and the Adrenal Cortex.*—It has been shown that the anterior pituitary gland exerts an inhibiting influence on wool growth mediated via the secretion of adrenocorticotrophic hormone (A.C.T.H.) acting on the adrenal cortex.

Injections of A.C.T.H. suppress wool growth almost completely, and when given over a short period, cause a break in the fleece similar to natural break.

Methods are being developed for the measurement of the concentration of adrenal cortical steroids in the blood, in an attempt to assess the significance of the adrenal cortex in determining the productive capacity of sheep for wool growth.

(*b*) *Experimental Histology of Skin and Hair.*—(i) *Development of Wool Follicles in Tissue Culture.*—Further observations have been made on the development of wool follicles of different types which have been grown in tissue culture. In skin from an 80-day foetus, primary wool follicles, which were at an early stage of development, produced keratinized wool fibres at a slightly faster rate than in the foetus *in utero*, but secondary follicles did not form. Sebaceous glands were formed and sudoriferous glands underwent normal differentiation. The primary follicles in explants from a 98-day foetus produced many large wool fibres, but development was slower than in the foetus. There was some evidence for the formation of new secondary follicles *in vitro*. There was little or no development in the wool follicles in skin from a 125-day foetus.

(ii) *Proposed Terminology for Wool Follicles.*—A unified system of terms and symbols for wool follicles in sheep has been proposed. It provides for a recent contribution to the study of wool follicle development, namely, the distinction between *original secondary follicles* which arise directly from the epidermis, and *derived secondary follicles* which arise from them by branching.

(iii) *The Development of the Epidermis and Hair Canals in the Merino Foetus.*—A histological study has been made of the development of the epidermis and hair canals in Merino foetuses ranging in age from 69 days to birth.

(iv) *The Development of Marsupial Skin and Hair.*—Observations have been continued on the development of skin and hair in the brush possum (*Trichosurus vulpecula*) and the bandicoot (*Perameles nasuta*). A breeding colony of the brush possum has now been established for studying many of the problems of skin biology. Observations on the growth of brush possums and bandicoots in captivity are continuing.

Bandicoots are born before the first appearance of pelage hair follicles and it has been possible to remove skin samples at intervals throughout the animal's entire development within the pouch and later growth. On the mid-side region, the first hair follicles appear about eleven days after birth and the first hairs emerge on this region at about the 40th day of age. Hair growth is cyclic. Before the end of each hair growth cycle, a new generation of follicles arises by branching from most of the existing follicles. This method of hair replacement has not been previously described in any mammals.

(*c*) *Studies of Skin and Fleece Development. Effects of Early Nutrition.*—Earlier observations on the effects of prenatal nutrition of the ewe on the birth weight of lambs and the development of the skin follicles at birth have been confirmed.

A low plane of nutrition to four months of age was observed to have a marked effect on the maturation of secondary follicles at that age—only 35 per cent. of follicles had come to maturity—whereas in animals on a high plane of nutrition, some 80 per cent. of follicles were mature.

At four months of age, all animals were transferred to a high plane of nutrition. The lambs which were initially "low" showed considerable recovery, and by eight months, had matured approximately 70 per cent. of follicles, while the lambs which were initially "high" had matured between 85 and 90 per cent. of follicles. The histological observations are continuing, and when the lambs are twelve months old, detailed wool production studies will commence.

(*d*) *Fleece Structure and Wool Production.* (i) *Mosaic Sheep.*—Detailed comparative studies of the fleeces of ten mosaic sheep have indicated that, at a given nutritional level, wool production per unit area is the result of the interactions of fibre number, fibre length, and fibre diameter, and the interrelationship of length and diameter. From these observations, it is apparent that the relationship of fibre number to unit area wool production varies with nutritional level and that there are density-dependent and density-independent components.

Detailed histological studies of the skin and wool of mosaic and mutant fleece types are in progress to identify the factors responsible for differing follicle productivity. This work is being done in collaboration with the Animal Genetics Section.

The antigenic relationships of normal and mosaic regions of the skin are being investigated.

(ii) *Birth Coat Studies.*—Investigations of the relationship of birth coat grade to adult fleece characters have shown that increasing coarseness of the birth coat is associated with increasing variability of fibre diameter in the adult fleece. This increased variability results primarily from an increased diameter of fibres in primary follicles.

(*e*) *Experimental Manipulation of Skin.* (i) *Skin Transplantation.*—The technique of autotransplantation of skin has been used to study the effect of marked changes of fibre density on fleece structure and wool production in lambs and adult sheep.

(ii) *Surgical Stretching of Skin.*—A technique has been developed to decrease follicle number per unit area as a method for studying the relationship of number to unit area of wool production.

(iii) *Skin Grafting in Mice.*—The genetics of skin graft incompatibility are being studied in mice by using mutant markers and backcrossing to A-strain inbred mice. Preliminary evidence shows that the inheritance of incompatibility is different for primary and secondary challenges. This result is unexpected on the basis of the accepted immune response theory of skin homograft incompatibility.

The autonomy of hair growth cycles is being studied in Naked mice. It has been found that the stage of hair growth at transplantation influences the autonomy of the hair growth cycle of transplanted skin.

Dose-time responses of homograft reactions and the effect of conditioning with skin extracts are being studied, (These studies are being made in collaboration with the Animal Genetics Section.)

(*f*) *Methods of Determining Fibre Population Density.*—Fibre population density is well recognized as an important trait in the selection of wool producing sheep. In the determination of density, two methods, the " cast " method and the " trephine " method, are used. In the first procedure, the estimation is made from a wool sample clipped from an area of skin; in the second, wool follicles are counted in a histological preparation of a sample of skin.

An experiment was carried out to compare and relate the densities obtained by these methods. It was found that when the areas of skin concerned were determined in a relaxed condition, the density obtained by the cast method was 40 per cent. greater than that obtained by the trephine method; but, when these areas were determined in a taut condition, the results were similar. The accuracy of the methods was similar when conditions of skin tension at sampling were the same, but more repeatable results were obtained by sampling with the skin in a taut condition. When skin samples are taken from relaxed skin more repeatable results are obtained if no correction is made for shrinkage of the skin sample. Although there may be differences between strains of sheep in elasticity of the skin, this was not important in the taut skin technique of sampling. A paper embodying these results has been prepared for publication.

(*g*) *Feed Intake and Wool Growth of Grazing Sheep.*—Differences between strains of Merino sheep grazing natural pasture at Prospect have been examined on the basis of differences between body weight, levels of wool production, and weight and chemical composition of faeces. Studies on fine-wooled and strong-wooled strains suggest that: (i) the intake of nitrogen is proportional to body weight; (ii) the fine-wooled strain is the less selective under these experimental conditions; and (iii) the strong-wooled strain is 15-20 per cent. more efficient than the fine-wooled strain in converting feed nitrogen into wool.

Digestibility studies with a ration, consisting of equal parts lucerne chaff and wheaten chaff, have indicated that both strains have similar digestive efficiencies.

(*h*) *The Efficiency of Wool Growth.*—Experimental observations of the wool growth of sheep fed at different levels show that the efficiency of conversion of food protein into wool falls with increasing protein intake. The efficiency of utilization of food protein for wool growth of sheep fed at maintenance levels is considerably greater than the efficiency of sheep fed *ad lib.*

These results suggest that restricted grazing of improved pastures by a greater number of sheep allowed to graze for a limited time could lead to greater wool production per acre. Similar results could not be expected from overstocking, because this would lead to the depression of pasture growth.

It has been found that the food intake of sheep fed *ad lib.* in pens is closely proportional to body weight. Wool growth per unit body weight may therefore prove to be a better measure for purposes of selection than wool growth per head.

Detailed experiments have been commenced to determine those stages in the process of conversion of feed nitrogen to wool where differences in efficiency between individual sheep occur.

17. Sheep Diseases.

(Division of Animal Health and Production.)

(*a*) " *Toxaemic Jaundice* " *of Sheep* (Animal Health Laboratory, Melbourne).—This investigation has been resolved into the study of the two diseases, chronic copper poisoning and heliotrope poisoning. Laboratory studies have constituted the major part of the programme during the year and are summarized under the following headings—

(i) *Chronic Copper Poisoning.*—Following the earlier demonstrations that molybdenum in the diet of the sheep was an important factor in the limitation of copper retention, but that this limitation was effective only when the diet also contained adequate amounts of inorganic sulphate, the work has been directed towards the elucidation of the mechanism of this interaction. Only limited progress has been made, but it is apparent that excretion of free sulphate through the kidney is an essential factor. High protein diets, which like high inorganic sulphate intake, raise the excretion of free sulphate in the urine, will limit copper retention when the diet contains molybdenum.

Other inorganic components of the diet which may interfere with the copper/molybdenum/sulphate interaction are being investigated.

(ii) *Heliotrope Poisoning.*—Studies have been concentrated on the acute and chonic toxicological and pathological effects following administration to rats of the pure alkaloids isolated from *H. europaeum.* It has been shown that the same histopathological picture, as seen in sheep dying under grazing conditions, can be reproduced in rats. These investigations are being continued.

(*b*) *Copper Metabolism Studies on Sheep in Western Australia* (Department of Agriculture, Perth).—The copper content of herbage samples from the Wiluna area, although still relatively high, was lower than in samples collected in 1953; this may have been related to the higher rainfall of 1955. Liver samples from sheep had a lower copper value than some collected in 1954; nevertheless, one sample contained 1900 p.p.m., and was histologically abnormal. An outstanding feature of the Wiluna herbage is the high manganese content.

(*c*) *Sheath Rot in Sheep* (Regional Pastoral Laboratory, Armidale, New South Wales).—Field studies have been commenced at Armidale. The incidence of the disease is being surveyed in relation to pasture and soil types and a critical evaluation is being made of surgical and other possible means of prevention and cure.

(*d*) *Mycotic Dermatitis* (McMaster Laboratory).—Laboratory tests were carried out to see whether any of the common dipping agents were bactericidal for *Nocardia dermatonomus*. It was found that 0.1 per cent. diazinon inhibited growth, and 0.01 per cent. greatly retarded growth. Arsenious oxide at a concentration of 0.01 per cent. and 0.001 per cent. completely inhibited growth. A field trial with new-born lambs is about to be commenced, to investigate whether either of these agents would be an improvement on 1/500 copper sulphate.

Experiments last year indicated that the resistance of older animals to infection with this organism was not associated with an antibody response. A study has been initiated on the inhibitory effect of wool fats on the growth of the organism. It was found that growth of the organism was inhibited by capric, myristic, and lauric acids. Undecylenic acid was also found to be inhibitory. An ether extract of the fleece of a sheep resistant to artificial infestation inhibited growth of *N. dermatonomus* at a concentration of 0.25 per cent.

(*e*) *Footrot*.—Further work has been done on the treatment of this condition. The intravenous administration of chloromycetin failed to cure eight of twelve affected feet after paring. In a limited trial on the curative effect of the oral administration of chloromycetin, the results were inconclusive. Four sheep, with a total of nine affected feet, were pared and foot-bathed weekly in 5 per cent. formalin. After four treatments, all feet were apparently cured, but three weeks later, one sheep relapsed in three of four affected feet. It is not always easy to decide whether sheep have been cured by formalin soon after treatment. A commercial colloidal sulphur preparation was tested on ten affected feet. A total of seven feet were cured, after three treatments.

Fusiformis nodosus was found to be sensitive to terramycin, but not to polymixin B. sulphate. Preliminary laboratory trials with terramycin were promising, and field trials indicated that it is at least as efficient as chloromycetin, but its instability in alcohol presents some practical difficulties.

The cultural requirements of *F. nodosus* are being studied with a view to investigating the pathogenesis of the disease and the antigenicity of the organism. It has been found that urea extraction of prekeratin from the sheep's hoof, and subsequent digestion, yields a product capable of supporting the growth of *F. nodosus*.

(*f*) *Foot Abscess*.—The sensitivity of three strains of *Fusiformis necrophorus* was tested against chloromycetin, terramycin, aureomycin, penicillin, streptomycin, polymixin B. sulphate, and sulphamezathine. Chloromycetin was found to exert the greatest inhibtion, followed by terramycin and penicillin. The results of field trials with chloromycetin, penicillin, and sulphamezathine were disappointing except in early cases.

(*g*) *Brucellosis of Sheep* (Animal Health Laboratory, Melbourne).—As a preliminary to the study of the general pathology of the disease, serological methods of diagnosis are being investigated. Complement fixation tests have proved to be of value in indicating that infection has occurred, but variations in antibody titres are too small to serve as a guide to the course or extent of infection. Various agglutination techniques have failed to give satisfaction; other serological methods are being tried. Selective culture media for the isolation of the causal organism from heavily contaminated material have been tested and the results are encouraging.

(*h*) *Fleece-rot* (*McMaster Laboratory*).—A diphtheroid organism was isolated, sometimes in pure culture, from the dermatitis associated with fleece-rot. This organism in the presence of moisture consistently caused a dermatitis, while *Pseudomonas aeruginosa* produced the green discoloration of the fleece, but no dermatitis. The two organisms together produced a severe dermatitis and discoloration of the fleece. The inhibitory effect of the common dipping agents on the growth of the diphtheroid organism was tested. It was found that dieldrin was the most effective and inhibited the growth of the organism at a concentration of 0.01 per cent. A field trial is in progress to test the value of treatment with dieldrin to control the development of fleece-rot.

(*i*) *Mortalities Off-shears*.—An investigation has been commenced of the fundamental cause of death in sheep on exposure off-shears. Pilot experiments have confirmed the general experience that wind and rain are more dangerous than cold.

18. INTERNAL PARASITES.

(Division of Animal Health and Production.)

(*a*) *Studies on Anthelmintics* (McMaster Laboratory).—(i) *Phenothiazine*.—To test the value of repeated doses of phenothiazine for suppressing egg laying by nematode worms, and consequently reducing contamination of pastures, groups of sheep were treated with 3 g. phenothiazine every second day, 5 g. twice weekly, or 10 g. weekly. All treatments reduced egg counts to low levels, but most faecal cultures yielded a few *Trichostrongylus* spp. larvae. Five sheep run in a 1-acre paddock were given free access to a 1:15 phenothiazine-salt mixture. Over sixteen weeks, the average daily consumption was 9.9 g. per sheep equivalent to approximately 0.6 g. phenothiazine. Four of the sheep developed medium to heavy infestations with *Haemonchus contortus*.

(ii) *Phenothiazine Derivatives*.—A phenothiazine substituted compound, 2-chloro-7-methoxyphenothiazine, which was very effective against *Aspicularis* and *Syphacia* infestations in mice, failed to show similar effects in sheep. Tests on sheep will be repeated after the compound has been ground to a fine particle size.

In trials against oxyurids in mice, the addition of riboflavin to phenothiazine or to 2-chloro-7-methoxyphenothiazine, or of ascorbic acid or nicotinamide to the latter, did not affect anthelmintic activity. Phenothiazine and 3-methoxy-6-chlorophenothiazine were effective, but 2, 8, and 3, 7-dichlorophenothiazine and 2-chloro-phenothiazine were ineffective. This work is being carried out in co-operation with the Department of Organic Chemistry of the University of Sydney.

(iii) *Piperazine Compounds*.—The complex, piperazine-1-carbodithioic betaine, showed variable and generally poor anthelmintic effects against *T. colubriformis* even when delivered into the abomasum. Doses exceeding 15 g. may be toxic. Piperazine adipate in 4-g. doses was effective against *Oesophagostomum columbianum*, but not against *H. contortus*. Even 20-g. doses into the abomasum were ineffective against *T. colubriformis*. The following were ineffective against the oxyurids of mice: *N*-methoxyethyl-piperazine dihydrochloride; *N,N*-dimethoxyethyl-piperazine dihydrochloride; *N,N*-bishydroxyethyl-piperazine, *N*-hydroxyethyl-piperazine dihydrochloride. The addition of diketo-piperazine or alloxan to piperazine diacetate did not affect anthelmintic activity.

(iv) 1:8-*Dihydroxyanthraquinone*.—This compound was used in a field trial in Western Australia to control selectively *Chabertia ovina*. In the sheep treated monthly, the number of *C. ovina* eggs never exceeded 1.5 per g., but reached 414 and 221 in sheep treated monthly with copper sulphate-nicotine sulphate and untreated controls respectively.

(v) *Hexachlorethane-phenothiazine Mixture*.—Previous trials had shown that hexachlorethane alone had little effect on *T. colubriformis*. Further trials with 10- and 15-g. doses confirmed these results. A mixture of 5 g. hexachlorethane with 10 g. phenothiazine, injected into the rumen, was not effective in any of three sheep. When the dose was increased to 10 g. hexachlorethane, two of four sheep showed reductions in egg counts, and when increased to 15 g., four of seven sheep showed reductions. The dose of phenothiazine remained at 10 g. throughout because 15 g. of this compound usually shows marked anthelmintic effects against *T. colubriformis*. These preliminary trials suggest that there may be some additive effects with these two compounds.

(vi) *Lead Arsenate*.—Further trials with lead arsenate did not confirm earlier results which suggested that it may be very effective against *H. contortus* when injected into the rumen. Doses of 1-3 g. were effective in only three of twelve sheep. The higher dose rate caused loss of appetite and diarrhoea.

(vii) *Other Anthelmintics*.—Doses of 5 and 10 g. of 2-mercaptobenzthiazole or 6-nitro-mercaptobenzthiazole were not effective against *Fasciola hepatica*.

(viii) *Oesophageal Reflex*.—Phenothiazine is a useful indicator for the destination of a drench swallowed by sheep and has been used to compare the effects of drenching techniques. The dye appears in the urine within 30 min. when swallowed into the abomasum, but not until 120 min. when swallowed into the rumen.

Electrical stimulation of the pharyngeal mucosa did not influence the oesophageal groove reflex. Some sheep showed immediate but transient mechanical stimulus when the nozzle of the drenching apparatus was placed in the mouth, followed by a strong and prolonged response when copper sulphate solution was squirted from the nozzle.

(ix) In Vitro *Screening Technique*.—Observations are being made to test the possibility of using the " inner tube " technique of culturing faeces to give an *in vitro* screening test for possible anthelmintics.

(*b*) *Control of Fascioliasis*.—The ecology of the intermediate host *Simlimnaea subaquatalis* is being studied. It was observed to commence breeding in August in habitats on the central and southern tableland regions of New South Wales, and in artificial habitats at the laboratory. Habitats at Oberon sprayed with copper pentochlorphenate in July were free of snails to mid-September. Spraying of four centres on the Central and Southern Tablelands in September-October gave very high initial kills of snails, but repopulation was rapid within three months. Spraying with a 1 per cent. solution of copper sulphate also gave a high initial kill, but was followed by rapid repopulation. *S. subaquatalis* were observed to die on one area in the late spring, while *Bullinus* spp. in the same habitat were unaffected. A report of liver fluke infestation in sheep in the County of Cumberland led to the first discovery of *S. subaquatalis* in this area.

(*c*) *Epidemiology*.—(i) *Field Observations in Western Australia and Tasmania* (McMaster Laboratory).—At the " Glen Lossie " Field Station, Kojonup, Western Australia (Division of Plant Industry, C.S.I.R.O.), a separate group of lambs from about eight weeks of age onwards was given a challenge dose of 30,000 *T. colubriformis* larvae each month. The infestations developed in all groups until the lambs were eight to nine months, when they appeared to develop resistance. Unusual heavy summer rains made conditions abnormal.

At Tarwongup, 85 per cent. of fleeces from undrenched sheep showed a break in the wool, 72 per cent. of fleeces from sheep drenched monthly with copper sulphate-nicotine sulphate were affected similarly, as were 50 per cent. of the fleeces from sheep drenched with 1:8-dihydroxyanthraquinone, which selectively controls *Chabertia ovina*. The groups cut 9.25, 9.7, and 10.6 lb. wool per head, respectively.

At Bridgetown, the worm burdens of autumn lambs increased from August to September and rose sharply in November. *Trichostrongylus* spp. increased in May-June. *H. contortus* did not increase here in autumn-dropped lambs during their second spring. At Beverley, infestations were very light throughout the year.

Further studies of the development of natural resistance to *T. colubriformis* are being made at Cressy, Tasmania (Tasmanian Department of Agriculture). Naturally acquired infestation rose during January-February. Lambs given 8,000 larvae at eight weeks of age, and those given 30,000 larvae at nine weeks, appeared to resist infestation, but those dosed with larvae in October, November, December, and January did not resist natural infestation.

(ii) *Field Observations on Irrigated Pasture*.—At Falkiner Memorial Field Station, Deniliquin, New South Wales (Division of Plant Industry, C.S.I.R.O.), two groups each of twenty weaners were run together on irrigated pastures. One group was not drenched and the other was drenched, every second month, with phenothiazine. A third group, run separately, had access to a phenothiazine-salt mixture. From September, 1955, to February, 1956, average weight gains per head for the three groups in order mentioned were 11.1, 10.5, and 11.7 kg. respectively. Worm infestations were low throughout.

(iii) *Larval Populations on Sown and Native Pastures* (Regional Pastoral Laboratory, Armidale).—At Armidale, the measurement of larval populations on sown and native pastures, using a direct recovery technique, was terminated in November, 1955. Worm-free lambs are now being used to provide additional information on the seasonal occurrence of different species of infective larvae. Except for a short period in autumn, 1955, the number of larvae per unit area recovered from the sown pasture was usually higher than from the native pasture, but mean worm-egg counts of the sheep on the sown pasture (four sheep per acre) compared with the native pasture (one sheep per acre) would offset the lower output of worm eggs per sheep. Other factors such as temperature and moisture may also have influenced the number of larvae recovered. The measurement of temperatures in faeces in sheltered and exposed situations, as exemplified by a dense-sown and an open native pasture, have shown only small differences in minimum temperatures between the two situations. However, large differences in the maximum temperatures do occur and may be of importance in the development and survival of larvae.

(iv) *Epidemiology of* Trichostrongylus *spp*.—It has been suggested that the dominance of *H. contortus* infestations in summer rainfall regions may influence the level and course of *Trichostrongylus* spp. infestations. From weaning in April, 1955, a group of Merinos at Armidale was drenched each fortnight with carbon tetrachloride, with a view to suppressing *H. contortus* infestation. As measured by egg counts, a satisfactory suppression was achieved only during the winter months, when reinfestation would normally be at a very low level. There was no indication of any alteration in the level or course of *Trichostrongylus* spp., except in February, 1956, when a partial suppression of *H. contortus* was associated with a transient increase in *Trichostrongylus* spp. infestation.

(*d*) *Resistance and Immunity to Nematode Infestation* (McMaster Laboratory and Regional Pastoral Laboratory, Armidale).—The advent of pregnancy did not affect the acquired resistance of ewes to *T. colubriformis*. Exsheathment of larvae has been found to proceed normally in the rumen of sheep resistant to *H. contortus*. An initial infestation of *T. colubriformis* in lambs younger than five to six months heightened the resistance of only a small proportion to a challenge dose of larvae. An initial infestation of *T. colubriformis* given to lambs five to six months old heightened their resistance to a challenge dose given eight weeks later. When challenged three weeks after initial infestation, there was little evidence of heightened resistance and the effect was additive when the interval was five weeks. Initial infestations in lambs five to six months of age of 2,000 or 5,000 *T. colubriformis* larvae were not as effective as 15,000 larvae in stimulating resistance. The intermittent intake of *T. colubriformis* larvae was not as effective in promoting resistance as was continuous infestation with adult worms. There was no evidence of cross-resistance between *T. colubriformis and T. axei*.

At Armidale, a group of lambs six to ten weeks old was dosed with 7,000 infective *T. colubriformis* larvae. There were no significant differences in worm-egg counts or in liveweights between these and a control group, after both had been exposed to natural infestation for six months, followed by a challenge dose of 25,000 infective larvae. However, in a second experiment, differences did occur between the egg counts of treated and control groups of lambs which were challenged with 40,000 larvae at two months, 48,000 at three months, and 50,000 at four months, after the initial dose of 7,000 larvae to the treated group. The first challenge dose resulted in heavy infestations and reduced liveweights in both groups, but, after the third challenge, egg counts were lower in the treated group. Two months after a final challenge dose of 25,000 larvae, given at six months, egg counts were again the same in both groups. In the course of this trial, eight of twenty lambs died in the control group compared with three of nineteen lambs in the treated group.

(*e*) *The Exsheathment of Nematode Larvae* (McMaster Laboratory).—This investigation has revealed the presence of a factor in ruminal fluid which stimulates infective nematode larvae to exsheath. The factor does not act directly on the sheath. An attempt is being made to isolate the factor from ruminal fluid but this work is still in the early stages. Both bile and blood serum exhibit a similar activity. The factor withstands temperatures up to 100° C., but is inactivated at an alkaline pH. Species of nematodes which normally only exsheath in the abomasum will exsheath in ruminal fluid, if the pH is reduced to that of the abomasal fluid. The moulting factor released by larvae stimulated by the ruminal factor will produce comparable changes in empty sheaths, as in sheaths containing live larvae. The moulting factor is capable of attacking sheaths only of the species from which it was derived. It is inactivated by temperatures about 60° C. but functions at 16° C. A series of ligation experiments showed that it is released from the vicinity of, but anterior to, the base of the oesophagus. Treatment of *H. contortus* sheaths with reducing agents has shown that –S–S– linkages are present in the region where the sheath fractures.

(*f*) Strongyloides papillosus.—*Strongyloides* infestation was encountered among sheep confined in pens under wet humid conditions. The anthelmintic effect was tested of phenothiazine (25 g.) gentian violet (5 g.) hexachlorethane (10 g.), and piperazine (4 g.). No treatment was successful. Spraying of the pens with 5 per cent. " Kerol ", a phenolic disinfectant, or 10 per cent. copper sulphate or copper pentachlorphenate failed to control the infestation.

(*g*) *Phenothiazine Synthesis* (MacMaster Laboratory).—Methods available for preparing *o*-aminobenzenethiols and substituted phenothiazines were re-examined and, in some cases, extended. Measurements of the lipoid-water partition coefficients of several more phenothiazine derivatives were made but the results could not be related to biological activity. Attempts are being made to synthesize dithiadiazapentacenes, which would be more soluble than phenothiazine and may be more effective. The scope and limitations of the Smiles rearrangement have been studied.

(*h*) *Phenothiazine-salt Licks* (Regional Pastoral Laboratory, Armidale).—The availability of salt blocks containing phenothiazine has stimulated interest by graziers in this form of worm parasite control. As a preliminary to investigating the method, salt has been made available to sheep on sown and native pasture for the past eight months. Consumption has been irregular, but has been approximately 3.6 g. per head per day on the sown and 5.4 g. per head per day on the native pasture.

(*i*) *Parasite Physiology and Toxicology* (McMaster Laboratory).—(i) *Second Stage Larvae of* Nippostrongylus muris.—An attempt to culture second stage infective larvae of *N. muris* has shown that more information is required about the specific stimuli of the physiological environments at different stages of development, and about the physiological and biochemical differences between the successive stages of the parasite itself.

(ii) *Fourth Stage Larval Cuticle of* N. muris.—It has been found that the fourth stage larval cuticle of *N. muris* consists of a water-soluble protein. Of the amino acids present, glycine, proline, hydroxyproline, and tyrosine are in large amounts. Its constitution, together with other characteristics, resemble collagen, although it fails to swell in 0.2 N hydrochloric acid. More specific tests are in hand.

(iii) *Anthelmintic Investigations against* Aspicularis.—The stearate of the asymmetric complex trisethylenediamine Co III was found to be a highly effective anthelmintic against *Aspicularis* infestations in mice. The racemate as well as the separate *d*- and *l*-forms were equally effective. The symmetric hexamine Co III complex was completely ineffective. The ions of both complexes have three charges and they differ negligibly in size. This work was done in collaboration with the Chemistry Department, University of Sydney, and sufficient quantities are being synthesized to test their anthelmintic properties in sheep.

(iv) *Pathology of* N. muris *Infestations in Rats*.—The efficiency of digestion of infested and non-infested rats was compared by estimating the organic matter in the total food ingested and in the faeces excreted. No difference between infested and non-infested rats could be discerned.

(v) *Biosynthesis of Adenine*.—The biosynthesis of adenine and adenylic acid has been studied with mutant No. 44206 of *Neurospora crassa.*

19. EXTERNAL PARASITES.

(Division of Animal Health and Production.)

(*a*) *The Ecology of Ectoparasites* (McMaster Laboratory).—The object of these studies is to determine why populations of permanent ectoparasites fluctuate and the factors governing their distribution on the host. The analysis of the oviposition behaviour pattern of lice has been completed. *Dammalinia ovis* and *D. equi* will lay eggs only when exposed to a temperature approximating that of the skin. This temperature zone is normally near the skin, but is determined in sheep by fleece tip temperature and depth of fleece. This explains why eggs are not found on the extremities where the temperatures are frequently lower. Humidity has no influence on the behaviour pattern, but high humidities appear to have a depressant effect on the number of eggs laid. A fibre of suitable diameter must be present to provide a touch stimulus necessary for oviposition. For example, in the horse, *D. equi* can lay eggs on fibres of the diameter of the body coat, but not on the course hairs of the mane. On he other hand, *Haematopinas asini* can lay eggs on the oarse fibres of the mane. Consequently, annual shedding of the coat has a more severe effect on the *D. equi* population than on the *H. asini*. The influence of grooming ffects distribution in some hosts. For example, the eggs of *Polyplax serrata* are found normally only on the head of the mouse, but when grooming is prevented, the eggs are distributed over the whole body.

(*b*) Psorergates ovis.—The toxicities of malathion, diazinon, and the delta-isomer of BHC to this parasite have been tested. Malathion, 0.02 per cent., produced a good kill on a patch test and subsequently a field trial was arranged. The early results are promising. Diazinon, 0.05 per cent. and 0.01 per cent., have been found successful in a patch test and a field trial is proposed. Delta BHC was not successful in a patch test at a concentration of 0.02 per cent.

(*c*) Ixodes holocyclus *Toxin.*—Larvae, nymphs, and adults of *I. holocyclus* induced similar symptoms and death in mice. The carbohydrate metabolism of the muscle of paralyzed mice was investigated and a disturbance was found in glycolysis, localized between the glucose-1-phosphate and 3-phosphoglyceric acid levels. Efforts are being made to define the disturbance more clearly and to determine whether this is a primary effect of the toxin.

It was observed that engorged female *I. holocyclus* produced a pink cuticular excretion which, on injection, produced paralytic symptoms and death of mice. Arrangements are in hand to obtain enough ticks to enable collection of sufficient pigment to proceed with its identification. A preliminary examination has shown that the substance exhibits a red fluorescence under u.v. light. A new species of tick closely resembling *I. holocyclus* has been found on opossums. It does not, however, kill mice.

(*d*) Dammalinia ovis.—Aldrin and malathion are being used in a field trial to check their effect on lice. It is too soon to assess the results critically.

20. PROTECTION AGAINST BLOWFLY STRIKE.

(Division of Animal Health and Production.)

The experiments at the Veterinary Parasitology Laboratory, Yeerongpilly, Queensland, were the responsibility of Dr. J. H. Riches, who worked in close co-operation with Mr. P. J. O'Sullivan, Queensland Department of Agriculture and Stock. After Dr. Riches's death in September, 1955, the work has been carried on by Mr. O'Sullivan. The Yeerongpilly Laboratory continued to supply the sheep and the cost of their maintenance, and also to provide assistance for maintaining the cultures of blowflies.

Malathion, when jetted into the fleece at concentrations up to 0.25 per cent., proved to have no anti-adult properties, and to protect against larval implants for only four to six weeks. Under the same conditions, dieldrin gave protection for eighteen weeks. Considerable attention was given to diazinon. In the first experiment, a concentration of 0.1 per cent. allowed no larval implants to establish themselves for the nineteen weeks that the sheep were under observation, and a concentration 0.05 per cent. was almost as efficient. In a second experiment, an 0.01 per cent. concentration was effective for twenty weeks, but not after 24 weeks, while 0.05 per cent. was still effective at 33 weeks. In both experiments, the animals treated with this insecticide were exposed to heavy and continuous rain from the 25th week.

An experiment to determine whether length of fleece influenced insecticidal persistence has been completed. Two compounds, dieldrin and diazinon, at 0.025 per cent. concentration, were jetted into sheep with fleece lengths of less than 1 inch, 1-1¾ inches, and 2½ inches or longer. The protection given by dieldrin broke down in all groups by the ninth week, but that given by diazinon persisted in all groups for seventeen to nineteen weeks. There was no correlation between length of wool and duration of protection against blowfly strike.

Investigations were continued on the systemic administration of insecticides. BHC, aldrin, and dieldrin in peanut oil at dose rates of 50 mg. and 100 mg./kg. were used. Aldrin and dieldrin at the lower dose rate and BHC also at 100 mg./kg. proved inefficient in preventing larval development in all sheep. Aldrin and dieldrin at 100 mg./kg. prevented the development or larvae for at least eighteen weeks, but at this dose rate these insecticides carry a high risk of serious toxicity. Systemic administration has no value for the treatment of struck sheep, as the larvae are not affected for seven to eight days after injection.

21. SHEEP BLOWFLY.

(Division of Entomology.)

(*a*) *Ecological Studies.*—Research on the sheep blowfly at the Division of Entomology during the past season has been devoted largely to the improvement of techniques for use in future ecological studies.

Progress has been made with the design of a "knock-down" trap which will minimize self-damage by blowfly specimens after capture. The object of this type of trap is to enable the maximum amount of information to be obtained as to age structure, fertility, &c., of the wild population from a study of the physical condition of trapped flies in comparison with marked flies of known age, also caught in traps.

Attempts are being made to obtain a bait material which can be used as a substitute for whole liver, while eliminating its disadvantages. Refinements in the marking of flies with fluorescent dusts as they emerge from the puparia are also being investigated.

(*b*) *Some Factors Affecting Oviposition by* Lucilia cuprina *on Sheep.*—Past workers have shown that when cotton wool plugs soaked with a solution of indole and ammonium carbonate were placed on live sheep they induced more oviposition by *L. cuprina* than when placed in small, *in vitro* preparations of clipped fleece or on sheep skins. A "sheep" (S) factor possessed only by live sheep was postulated to explain this. During the past year attempts have been made to determine the nature of the "S" factor and to examine other aspects of the oviposition by *L. cuprina* on sheep.

It has been found that some of the difference between the amounts of ovisposition on live sheep and on *in vitro* preparations is due to difference in surface area. Further studies are being carried out to investigate other factors such as temperature, moisture, and carbon dioxide tension.

The presence of cavities between the staples of wool is a very important factor. Indole plugs in open-fleeced sheep receive more eggs than do plugs in sheep with dense, compact fleece. The eggs are almost always laid in the cavities and not on the surface of the fleece. These differences in texture may well explain the differences in "S" factor which it is claimed occur from sheep to sheep.

22. OTHER SHEEP INVESTIGATIONS.

(Division of Animal Health and Production.)

(*a*) *Clover Oestrogens* (Department of Agriculture, Perth.)—Fractions prepared by the Chemistry Department of the University of Western Australia have been tested by a bioassay method in immature mice; changes in uterine weight were noted in the assessment of oestrogenic activity. The separation of the active fraction has proved difficult. A second chromatography on silica gel gives no separation whatever. Some separation can be obtained on paper (or cellulose powder) with butanol at high pH values, but considerable decomposition of the active oestrogen occurs. More promising results have been obtained by using acid eluents for cellulose powder chromatography.

(*b*) *Phalaris Staggers* (Regional Pastoral Laboratory, Armidale, New South Wales).—No cases of phalaris staggers occurred in Romney Marsh or Merino weaners grazing on a phalaris and white clover pasture at "Chiswick" during 1955.

There is evidence that the grazing of sheep and cattle on pastures with a high protein content may, under some conditions, cause disturbance of mineral metabolism. In the coming season, observations will be made on the serum magnesium and serum calcium levels of sheep on phalaris; these will be related to the protein content of the pasture, and the ammonia level of the rumen liquor.

(*c*) *Production from Native Pastures Used in Conjunction with Sown Pastures.*—In co-operation with the Division of Plant Industry, at "Chiswick", a study has been made of the animals and pasture production from land units containing increasing proportions of sown pasture (3.9, 15.5, 30.8, and 57.1 per cent.), with composite flocks of breeding ewes, weaners, and wethers.

This experiment, which extended over three years, has now been concluded. The results have indicated the range of increase in overall production per unit area which might be expected as the percentage of sown pasture increases. The wool production and liveweight increases in 1955 were 27 lb. wool and 58 lb. liveweight increase per acre, when 57.1 per cent. of sown pasture was available to the sheep compared with 9 lb. wool and 8 lb. liveweight increase per acre, with only 3.9 per cent. of sown pasture.

VIII. CATTLE.

1. GENERAL.

Products of the cattle industry—meat, hides, and dairy produce—represent over 20 per cent. of all Australian rural production. With the rapid increase in the population of Australia in the post-war period, home consumption of food commodities is outstripping primary production. If Australia is to maintain both its own food standards and an export of meat and dairy products on the pre-war level, research must find the means to increase the entire cattle industry.

Broadly, the approach of the Organization to the problems of the cattle industry comprises—

(i) A survey of the structure and interrelations of the various sections of the beef cattle industry throughout Australia.

(ii) Studies designed to eliminate wastage and loss from disease in both beef and dairy cattle.

(iii) The exploitation of potentialities for improving nutrition by the development of sown pastures, scientific understanding of the characteristics and management of natural pasture, and study of the possibility of introducing desirable exotic species into natural pastures.

(iv) The development of systems of breeding designed to evolve more productive beef and dairy types for north Australian conditions.

The Organization's work on cattle problems has been carried out chiefly by the Division of Animal Health and Production, mainly in the Animal Health Laboratory in Melbourne, the National Cattle Breeding Station at "Belmont", near Rockhampton, Queensland, and the Veterinary Parasitology Laboratory in Brisbane, Queensland (*see* Sections 2, 3, 4, 6, 7, and 8 of this Chapter). The Division of Entomology has been concerned with work on the cattle tick (*see* Section 5 of this Chapter). The work of the Division of Plant Industry on pastures is also of great importance to the cattle industry (*see* Chapter III.). The work of the Animal Genetics Section on beef cattle is described in Sections 8 and 9 of this Chapter.

2. CATTLE DISEASES.

(Division of Animal Health and Production.)

(*a*) *Pleuropneumonia of Cattle* (Animal Health Laboratory, Melbourne).—The results of the study on the untoward effects (arthritis and carditis), following vaccination of very young calves at the tip of the tail with living culture, are being prepared for publication The value of intramuscularly administered chloromycetin in the treatment of arthritis, following intra-articular injection of virulent culture in young calves, was examined This type of infection was taken as a model of the untoward gluteal invasion known as "bad tails", which occurs in a small proportion of vaccinated adults. By using heavy and repeated doses of chloromycetin, amounting in all to 140 mg./kg. over a period of four days, the infection was eventually overcome, and a complete bacteriological cure was effected of this usually fatal infection. Investigations are proceeding. In an attempt to study the fate of vaccine injected at the tail tip, the dye Evans' Blue was used. It was found that, whether subcutaneous or intracutaneous injection was performed with a dose of 0.2 ml., the dye reached the pelvic lymph nodes often in less than 2 hr.; sometimes even mammary nodes were stained. Anal nodes, which are characteristically involved in the "bad tail" infection, were often stained if of moderate size, but not when only a millimetre or so in diameter. It appeared that often these anal nodes are very small and perhaps may not then function in the lymphatic drainage of the tail tip. The relationship of these findings to the "bad tail" problem is being considered. Studies on the viability of vaccine again stressed the importance of low temperature. The finding in the Sudan that agar added to vaccine has an adjuvant effect has been confirmed, and further experiments are under way.

During the year 656,475 doses of vaccine were issued mainly for use in the beef cattle herds in the north of Australia, and sufficient complement-fixing antigen was supplied to laboratories within Australia and abroad to permit the testing of 26,000 cattle. Fundamental studies on the causal organism of the disease *Asterococcus mycoides* are reported elsewhere.

(*b*) *Mastitis in Dairy Cattle.*—The experimental herd at Werribee Field Station has remained free from infection with *Streptococcus agalactiae* for another year following upon elimination of the organism with penicillin, closing of the herd, and maintenance of good shed hygiene.

The herd is now to be used for other purposes, and work on mastitis has ceased, both at the Melbourne Laboratory and at the Werribee Field Station. Accumulated results from previous years are being analysed and prepared for publication in a second bulletin which will complete the history of the experimental herd.

(*c*) *Brucellosis of Cattle.*—In the study of the duration of the protection afforded by strain 19 vaccination those animals which proved resistant in the challenges to immunity, which were previously reported, were again subjected to exposure in a naturally contaminated environment while pregnant. In a control group of 22 non-vaccinated cattle, 73 per cent. were found to be infected at parturition, 50 per cent. having aborted. No evidence of infection was found in seventeen cattle vaccinated only in calfhood, or in nineteen vaccinated in calfhood and also three years later; all these cattle had received their calfhood vaccination seven years previous to this challenge to immunity.

In a limited number of blood cultures performed, *Br abortus* was isolated from twelve of fifteen cattle tested in the control, or non-vaccinated, group but not from any of five vaccinated cattle similarly tested. Some samples of udder secretion were obtained at fourteen-day intervals during the last few months of pregnancy *Br. abortus* was not isolated from any specimen obtained from vaccinated cattle, but, in the non-vaccinated control group, it was usual to isolate the organism from one specimen or more during this period, and sometimes before serological evidence of infection was found.

(*d*) *Haematuria Vesicalis of Cattle.*—In continuation of previous work, the excretion of abnormal products of tryptophane metabolism, and the possible action of such products as bladder irritants and carcinogens are being investigated. Techniques for the identification of small amounts of these substances in the urine of mice by means of paper chromatography are being tested. The results should prove most useful in the extension of the work to the examination of specimens of urine obtained from cattle in the field which are affected with haematuria vesicalis.

(*e*) *Infertility in Dairy Cattle.*—Herd infertility in dairy cattle presents a wide field for investigation in Australia, and C.S.I.R.O. is making its own contribution as well as cooperating with workers in several States. At the Melbourne Laboratory, specimens from some " problem " herds in Victoria have been investigated. It was previously reported that *Trichomonas foetus* has been isolated from cattle in one such herd and that it seemed likely that trichomoniasis might prove to be a major cause of infertility in Victoria. However, during the current year, material supplied by veterinary officers of the Victorian Department of Agriculture from about 50 herds was examined without any evidence of infection with *T. foetus* being found. C.S.I.R.O. investigations are now being widened, special attention being paid to vibriosis as a likely cause of infertility. Efforts are now being concentrated on the study of a small number of representative herds and in a search for evidence of infection with these or other causal microorganisms; if they are not found, non-infectious causes will be sought.

In laboratory work, agglutinating sera have been prepared against type strains of *T. foetus*, and field strains will be received for typing. Both a Victorian strain and one sent from New South Wales for typing have proved to be of the " Belfast " type. Cattle naturally and experimentally infected with *T. foetus* or *Vibrio fetus* have been kept at the laboratory to supply material for the testing of cultural and serological techniques.

(*f*) *Ephemeral Fever—Studies Made During the Outbreak of* 1955-56 (Veterinary Parasitology Laboratory, Yeerongpilly).—These studies included the attempted transmission of the disease by the injection of extracts of macerated insects. The species to be tested were collected in a suction trap, as used in the studies of allergic dermatitis of the horse, and suspended, when possible, over an infected animal in the febrile state. When such animals were not available, the trap was run in the vicinity of animals which had shown symptoms of the disease on some previous occasion.

The insects collected were separated into groups and the various Ceratopogonidae were held in cages for 48-72 hours. These were then killed and, after appropriate preparation, were injected immediately into calves seven-eight months old, or stored in tubes and held in dry ice. The tubed specimens were identified by Dr. E. J. Reye and forwarded by air to the Veterinary Research Station of the New South Wales Department of Agriculture at Glenfield, where, after appropriate preparation, they were injected intravenously into susceptible cattle in an insectary. However, none of these cattle showed the febrile reaction so typical of this disease. As the disease was prevalent in and around Brisbane at the time, the calves used in the transmission trials at Yerongpilly may have been resistant as a result of previous subclinical infection.

The following species of insects were tested: *Culicoides robertsi*, *Atrichopogon* spp., *Lasiohelea* spp., mixed *Culicoides* spp. (*robertsi*, *marmoratus*, *magnimaculatus*, *marksi*, and *pseudopalpalis*), and the mosquitoes *Culex sitieus*, *Aedes vigilax*, and *Aedes aurantiacus*. There was a slight rise in rectal temperature (2° F.) in the animal which received the extract from the *Lasiohelea* spp. but subinoculation from it gave no response.

When the known distribution of the Ceratopogonidae is compared with the distribution of ephemeral fever, the most prominent species are: *Culicoides robertsi*, *C. pseudopalpalis*, *C. marksi*, and *Lasiohelea* spp. (*L. townsvilliensis*). It is possible, however, that other species of *Culicoides* may have a wider distribution than is known at present.

3. INTERNAL PARASITES.

(Division of Animal Health and Production.)

The following investigations were carried out by the staff of the Veterinary Parasitology Laboratory, Yeerongpilly, Queensland.

(*a*) *Parasitic Gastro-enteritis of Cattle*—(i) *Susceptibility of* Bos taurus *and* B. indicus *to Helminth Infestation.*—Investigations have been commenced at the National Cattle Breeding Station, Belmont, Queensland, to ascertain whether crossbreeding of British breeds with *Bos indicus* may result in an increased resistance to helminth infestation.

(ii) *Seasonal Trends in Helminth Populations.*—No further observations were made on herds in south-eastern Queensland. Observations on the herd in Victoria, commenced in 1952, were also brought to a close. In this herd, it was evident that the infestations, which consisted mainly of *Ostertagia* spp., *Trichostrongylus* spp., and *Cooperia oncophora*, were most prevalent during the autumn to early spring.

(iii) *Studies on Infestation with* Haemonchus placei.—Attempts to ascertain the factors responsible for haemonchosis have been continued with calves reared worm-free and subjected to varying conditions of infestation.

These studies have shown that, with diets of lucerne or on a diet of twelve parts of oaten chaff and one part of lucerne chaff, and despite the number of larvae being administered either as a single dose, spaced doses, or daily doses, the infestation failed to persist.

The most outstanding feature of these experimental infestations was the high degree of resistance developed as a result of previous experience with the parasite.

In a few animals, heavy infestations of both adult and immature worms were seen. Such heavy infestations were most prevalent in animals which had been given 1,000 larvae daily, treated at monthly intervals with phenothiazine, and examined nine weeks after the challenge dose. It is of interest that in these animals, the egg count remained very low throughout the period of the trial. On slaughter, it was only ten-twenty eggs per g. It appears, therefore, that whilst the animal remains susceptible, egg counts may give a reasonably accurate estimate of the state of infestation, but that when resistance is developing, the count may be of little value.

These studies have indicated that an infestation superimposed upon an existing infestation will not develop to maturity, though it may survive as fourth stage larvae. They have also shown that these young forms may be important in the causation of haemonchosis, and may account in part for the slow recovery of animals which, according to their egg count, have rid themselves of their infestation.

(iv) *The Role of Copper Deficiency in Parasitic Gastro-enteritis.*—Studies have commenced to determine whether nematode infestation affects the level of copper in the liver of calves, and whether calves deficient in copper are more susceptible to infestation. The results to date from field trials do not suggest any such relationship. Trials are also being conducted with calves exposed experimentally to *H. placei* and with mice exposed to *Nematospiroides dubius*.

(v) *Biochemical Studies on Calves Infested with* Haemonchus placei.—Infestation of calves with this helminth produced no effect on levels of calcium, phosphorus, and protein in the host's serum over a period of three months. Repeated challenging of resistant calves to further infestation caused no alterations in the levels of albumin and globulins in the serum when weekly determinations were made for five months. In the first two weeks after infestation, there were significant decreases in haemoglobin values and red blood cell counts.

(vi) *Life History of* Haemonchus placei.—Moulting of third stage larvae in the abomasum of calves was found to occur between 36 and 76 hours after infestation. During this period, larvae were found deeply embedded in the ducts and tubules of the gastric glands. Moulting of fourth stage larvae to the adult stage occurred eleven-fourteen days after infestation. Commencement of feeding by the young adults was associated with general inflammation and ulceration in circumscribed areas of the mucosa at the site of attachment. As development of the worms proceeded during the fourth stage, there appeared to be some inhibition imposed on the growth of the least developed fourth stage larvae. In sheep simultaneously given mixed infections of *H. placei* and *H. contortus*, larvae of *H. placei* appeared in faecal cultures up to ten days later than those of *H. contortus*.

(vii) *Anthelmintics.*—Studies on the efficiency of phenothiazine against immature *H. placei* indicated that, at 0.2 g. per lb. body weight, it was highly efficient against worms eight and 42 days old respectively, but had little effect on worms fourteen days old, i.e. on young adults.

Several trials have been carried out with piperazine hydrate. Oral doses of 0.05, 0.1, and 0.2 g. per lb. body weight were ineffective against *H. placei, Bunostomum phlebotomum, Trichostrongylus axei,* and *Cooperia* spp., but were uniformly 100 per cent. efficient against *Oesophagostomum radiatum.* Although only light infestations of *Ostertagia* spp. were present, there were indications that the drug may have a useful anthelmintic action against this species. Oral doses of 0.02 g. per lb. body weight were only partially effective against *O. radiatum* and efficiency at this dose rate was not improved by the prior stimulation of the oesophageal groove reflex. Piperazine-l-carbodithioic betaine, tested orally at 0.05 g. per lb. body weight after closure of the oesophageal groove, was ineffective against *H. placei, B. phlebotomum, T. axei,* and *Cooperia* spp.

Neither of these piperazine compounds appeared to be effective against *Moniezia benedeni,* nor did mepacrine (atebrin) at a dose rate of 10 mg. per lb. body weight. Papain at a dose rate of 0.5 g. per lb. body weight was ineffective against *H. placei* and *Cooperia* spp. Lindane at 3 mg. per lb. body weight was ineffective against *B. phlebotomum.*

(viii) *Ecology of the Preparasitic Stages of Cattle Strongyles.*—Investigations into the development, migration, and survival of larvae under natural conditions have been continued. Routine observations are being made on soil and pasture samples at distances up to 36 inches from pats exposed at fortnightly intervals. Infective larvae have been found to migrate at least 36 inches from the pat. Larvae developed and migrated normally during June when the trials were commenced. Development in the pat continued thereafter until August but there was little migration, which was attributed to dry weather. Very little development occurred in the pats during the period September to January and very few larvae were recovered, probably owing to the effects of summer temperatures. Exposure to 45° C. for 15 min., for example, was found to be fatal under experimental conditions to the eggs of *H. placei.* Maximum temperatures in the pats during the day in December were 32° to 42.5° C. with a mean of 39.1° C. A solar maximum thermometer beside the pat recorded 80.5-87.9° C. Some larvae which reached the infective stage in August were still alive three months later.

(ix) *Infectivity of Strongyle Larvae.*—A trial to dete
mine whether the infectivity of the larvae of *H. placei*
associated with their intestinal fat content indicated th
larvae which had lost all fat from the intestinal cells aft
fifteen days' storage in water were still highly infecti
The trial also provided evidence that infective larvae le
than 24 hours old may have a very low degree of infe
tivity.

(x) *Recovery of Strongyle Larvae from Soil and Veg*
tation.—The sedimentation tube technique used for t
recovery of strongyle larvae from soil and pasture (1953-
Annual Report) has been improved and the time take
to carry out the technique reduced by approximately 4 h

(xi) *Egg Production of* Haemonchus placei.—Prelim
nary observations on an experimentally infested anim
indicates an egg output per female of approximately 1,00
eggs per day when production is at its peak, compare
with 5,000-10,000 eggs per day recorded for *H. contort*
in sheep.

(*b*) *Paramphistomes of Cattle.*—Three, if not fou
species of paramphistomes occur in Australian ruminant
The life histories of two of these, namely, *Ceylonocoty*
streptocoelium and *Paramphistomum ichikawai,* were pr
viously reported as involving the planorbid snails *Glyptan*
sus gilberti and *Segnitilia alphena* respectively. The thi
species *Calicophoron calicophorum* has been found to u
another species of planorbid snail, *Pygmanisus pelorius,*
its intermediate host. The cercaria of *C. calicophorum*
readily distinguishable from the cercariae of the oth
paramphistomes. Its prepatent period in calves is 80-9
days. *P. pelorius* appears to be confined to shallow tem
porary pools, such as occur in gilgai country. This sna
also acts as the intermediate host of a species of *Diplodisc*
which infests frogs.

4. The Cattle Tick.

(Division of Animal Health and Production.)

(*a*) *Host Reaction to Tick Infestation.*—Observatio
on stalled animals and on the same animals exposed und
natural conditions in the field showed that Zebu x Shor
horn cross-bred steers, with at least three-quarter Zeb
blood, were more resistant to infestation with the catt
tick *Boophilus microplus* than shorthorn steers of compa
able age. Not only were smaller numbers of adult tick
recovered from the former group, but the ticks were small
and laid fewer eggs.

The difference in tick infestation was greater under fiel
conditions where it is thought that the *Bos indicus* grou
did not pick up as many larval ticks as the *Bos tauru*
group. The nature of the hair cover may be
considerable importance in this respect.

Resistance in *B. taurus* animals is due to the develo
ment of a skin hypersensitivity. The loss of ticks occu
largely in the larval stage mainly through mechanic
means such as licking. Many are also killed by the serou
exudate at the point of larval attachment. This hype
sensitive state of the skin is also observed in the *B. indic*
group, but resistance resulting from development of a tru
immunity is also considered to be of importance in thes
animals. This immunity, especially denoted by the deat
of young adults while still attached to the animal, was see
in only a proportion of the animals comprising th
B. indicus group under study. It may be more prevale
in purebred *B. indicus* cattle.

However, individual animals of *B. taurus* breed may b
as resistant as, or even more resistant than, those of
indicus breed. This resistance is due to the developme
of skin hypersensitivity to a very high degree.

5. Biology and Control of the Cattle Tick.

(Division of Entomology.)

Research has continued at the Division of Entomolog
on the problems of acaricide resistance, the metabolism
DDT by ticks, the formulation of dipping fluids, method

of application of acaricides, and the testing of potential oxicants. The increasing complexity of the problems in he acaricidal field, however, emphasizes the need to consider the approach to the control of the cattle tick by methods quite distinct from those generally adopted at present. One alternative is to search for tick destroying agents exerting effects of a nature entirely different from those produced by recognized toxicants. On the other hand, a strong incentive is given to study of the employment of management methods which minimize the use of acaricides.

(*a*) *Acaricide Resistance.*—The chemical control of the cattle tick is now complicated by resistances which the ticks have developed to various acaricides. The substances to which cattle ticks are known to exhibit tolerance fall into three groups: (1) arsenic; (2) BHC, chlordane, toxaphene, dieldrin, aldrin, and others which appear to exhibit group cross-tolerance; and (3) DDT. Arsenic resistance in Queensland has received little consideration since the appearance of chlorinated hydrocarbon acaricides, though it is widespread. Resistance to BHC and the associated group of chemicals is also common, though DDT is generally satisfactory for tick control in such areas. DDT resistance is still local enough in occurrence for this acaricide to maintain a wide general usefulness. In the few localities in which ticks appear to exhibit resistance to all chlorinated hydrocarbons they can be controlled by the organic phosphate materials such as diazinon.

(i) *DDT-resistant Ticks.*—Laboratory tests showed that a strain of DDT-resistant ticks was susceptible to BHC, toxaphene, and dieldrin. Spraying an artificially infested animal indicated that these DDT-resistant ticks were also susceptible to diazinon.

Laboratory dosage mortality trials showed that there was no loss of DDT resistance in this strain after five generations had been raised without acaricidal treatment.

Research on house flies in other laboratories indicated that late-pupating flies were more resistant to insecticides than early-pupating flies, and that increasing divergence in the degree of resistance of substrains could be produced by progressive selection of early- and late-pupating flies from a culture over a number of generations. However, no parallel phenomenon was demonstrated by selecting early- and late-falling ticks of the DDT-resistant strain over three generations.

DDT-resistant ticks treated with a mixture of DDT and the synergist DME showed higher mortalities than those treated with DDT alone. The results suggest the presence in the DDT-resistant ticks of an enzyme, DDT-dehydrochlorinase, which is known to account for DDT resistance in some houseflies, though it has not been possible to isolate it chemically from the ticks.

(ii) *Toxaphene-resistant Ticks.*—Laboratory trials confirmed field evidence that a strain of toxaphene-resistant ticks was susceptible to DDT.

(iii) *Dieldrin-resistant Ticks.*—Laboratory trials with a strain of ticks from a property where dieldrin and other chlorinated hydrocarbon acaricides had failed to bring about control showed that the larvae were more than 2,000 times as resistant to dieldrin as were susceptible larvae. The adult ticks were also highly resistant to dieldrin. This, and a second strain suspected of being dieldrin-resistant, were readily controlled by spraying with 0.05 per cent. diazinon or 0.05 per cent. " L13/59 ".

(*b*) *Dipping and Spraying Formulations.*—(i) *Selective Removal of Toxicants During Dipping*—The " stripping " of DDT from two different types of formulations has been studied. " Stripping " describes the removal by cattle from the vat of quantities of toxicant in excess of that expected in the volume of fluid retained in the coats of the cattle. In freshly prepared colloidal formulation no stripping was demonstrated, but as the fluid aged, high stripping values were generally detected. The stripping from a wettable powder formulation was lower and less variable than from the colloidal preparation.

Stripping has also been studied in colloidal formulations of dieldrin and aldrin which appear to parallel DDT colloid in regard to this behaviour.

(ii) *Dieldrin in a Dipping Vat.*—A vat was charged with 0.05 per cent. dieldrin as a colloidal preparation on a property where the ticks had previously been exposed only to arsenic. The kill of the ticks and the periods after dipping for which the cattle were protected against larval reinfestation were variable, owing partly at least to variation in the amount of stripping, but results were generally satisfactory.

The progeny of some ticks collected after the third dipping showed a considerable degree of dieldrin resistance, but in spite of this, adequate control was obtained at the fourth and fifth dippings. The formulation maintained satisfactory stability and no animals showed signs of toxicosis.

(iii) *Aldrin in a Dipping Vat.*—A vat charged with 0.05 per cent. aldrin gave a comparatively poor kill of ticks on the first dipping occasion. At the next dipping some animals were again treated at the same concentration, but the rest of the herd was dipped after the concentration had been increased to 0.1 per cent. aldrin. The kill of ticks on both groups was almost complete. High kills have also resulted from subsequent dippings, and protective periods have progressively increased. The stability of this formulation was also satisfactory and there were no signs of toxicosis in dipped animals.

(iv) *Endrin.*—Spraying cattle with 0.01 per cent. endrin resulted in the destruction of all stages of ticks with the exception of a small percentage of engorged nymphs.

(v) " *L13/59* ".—This organic phosphorus compound gave a complete kill of ticks when sprayed on to cattle at concentrations from 0.05 to 1.0 per cent. The protective period of the highest concentration was about five days.

(vi) *Chlorthion.*—This organic phosphorus compound has been tested as a spray at concentrations ranging from 0.1 to 0.5 per cent., which are higher than in tests previously reported. The kill of ticks at best was only fair, and the protective period less than three days. The animals suffered irritation and exhibited some swelling and inflammation in flanks and escutcheon.

(vii) " *Tedion V 18* ".—This material is a mixture of highly chlorinated diphenyl sulphones, recommended as a specific toxicant for red spider and other acarina. When sprayed on to cattle at a concentration of 1.0 per cent. active ingredient the kill of ticks was poor.

(viii) *Alternative Tick Destroying Agents.*—A beginning has been made on a programme of testing alternatives to biochemically active toxicants for cattle tick control. Emphasis in such work is on substances which interfere mechanically with respiration or waterproofing in the tick. The spiracles are being studied as a site of entry for tick-destroying agents. It was found that wool wax killed adult ticks when applied to the spiracles, and killed all stages of ticks when applied to cattle.

(*c*) *Systemic Acaricides.*—Experiments were made to determine whether beeswax could be used to prolong the systemic effect of lindane and dieldrin against cattle ticks, as it does with penicillin injections. No increases in the duration of systemic effects were observed.

(*d*) *Pasture Spelling Experiments.*—The principle of destocking paddocks to allow the majority of larval ticks to die out has been further tested for cattle tick control under widely differing conditions.

(i) *South Queensland.*—In an experiment at Amberley, cattle which were pastured alternately in two paddocks at four-monthly intervals, without any acaricidal treatment at all, remained very lightly infested throughout the year. On the other hand, cattle in a continuously grazed paddock were heavily infested for most of the year, and had to be sprayed several times during the active period of the ticks.

In connexion with proposed systems of pasture spelling in south Queensland, further information is being obtained on tick developmental periods and survival in pastures.

(ii) *Central and Northern Queensland*.—At Calliope, near Gladstone, 350-400 cattle were grazed in three paddocks in rotation, spelling the paddocks for from three months in summer to four and a half months in winter before returning the stock to them. Under this system of management the cattle remained very lightly infested, although dipped only in January and September, 1955, and in January, 1956.

6. Investigations with Dairy Cattle.

(Division of Animal Health and Production.)

(*a*) *Nucleus Stud Herds of Sindhi and Sahiwal Cattle* (Werribee Field Station).—The foundation stock for these herds, which were presented to the Commonwealth of Australia by the Government of Pakistan in 1952, were transported by air from Karachi to Port Moresby, Papua-New Guinea, in December of that year. After two years in quarantine there, permission was given for their introduction to a property in southern Australia and they reached the Werribee Field Station in January, 1955. During 1955, four pairs of Sindhi and five pairs of Sahiwal cattle were successfully mated, and all females had calved prior to 30th June. The 1956 calf drop in these herds comprises five Sahiwal and two Sindhi bulls, and one Sindhi heifer. Observations are being made to compare the skin and hair characteristics of these exotic breeds with those of British cattle. This is a co-operative project with the Department of Territories, Administration of Papua-New Guinea.

(*b*) *Progress in the Zebu-cross Dairy Herd* (McMaster Field Station).—This project has now been re-orientated. The original herd, based on Guzerat Zebu and European blood, proved unsatisfactory for milk and butterfat production. Except for a few animals kept for use in other observations, the herd was disposed of during the year. It has now been replaced by 50 Jersey heifers which are being bred by artificial insemination to Sindhi and Sahiwal bulls located at the Werribee Field Station (*see* preceding section). It is proposed to breed at least 25 F_1 heifers of each cross. The crossbreds will be tested primarily for production and temperament.

(*c*) *Coat Shedding Studies*.—These studies have been extended to include the Sindhi and Sahiwal cattle at Werribee Field Station, Victoria. Hair samples and skin biopsy specimens have been taken at monthly intervals since June, 1955. The pattern of coat shedding in the Sindhi and Sahiwal cattle appears to differ from that in European cattle. In European cattle, the mid side of the body is the last area from which the winter coat is shed, whereas, in the Sindhi and Sahiwal cattle, shedding is slowest in a roughly saddle-shaped area over the back.

(*d*) *Sweat Gland Studies*.—Observations were made on sweat gland size in skin biopsy specimens obtained from the mid side and dewlap regions of the Sindhi and Sahiwal cattle at Werribee, and on similar specimens obtained from the mid side of European dairy breeds. This work was carried out in co-operation with the Animal Genetics Section. A report on it has been presented for publication. The most significant finding was that the *Bos indicus* breeds had larger (2½ times) and more numerous (1½ times) sweat glands on the mid side than European cattle.

7. Beef Production in Australia.

(Division of Animal Health and Production.)

(I.) The following have been the activities of the William McIlrath Fellow in Animal Husbandry, with headquarters at the McMaster Laboratory.

(*a*) *Investigations in the Southern States*.—Co-ordination has again been provided in these investigations which are being conducted by the Departments of Agriculture in New South Wales, Victoria, South Australia, Western Australia, and Tasmania, and are proceeding according to plan. The observations at twelve centres, established with funds provided by the Australian Meat Board and Rural Credits Development Fund of the Commonwealth Bank, have been continued. These include: seasonal growth curves, comparative breed studies, sire production and progeny testing, carcass appraisal investigations, yard- and stall-feeding of steers.

(*b*) *Other Beef Cattle Investigations*.—These have included work on the feeding of stud cattle, vitamin A requirements, and quantitative body composition analysis using the anti-pyrene injection technique.

(II.) Investigations concerned with beef production at other Divisional centres are listed below.

(*a*) *Environment Control of Coat Changes in Cattle* (University of Queensland). (i) *The Role of Nutrition*.—Indications from a preliminary experiment were that, although length of day is the major influence in coat shedding, the plane of nutrition also influences it. The effect of nutrition in this regard, however, appears to vary appreciably among individual animals.

(ii) *Effect of Equatorial (Constant-level) Light Environment*.—As seasonal light change regulates coat cycles in European breeds of cattle, it was decided to observe what coat changes such cattle would undergo if transferred to a constant-level light environment such as that at the Equator; also, whether or not the time of year at which the transfer took place was of any significance. Animal stalls were used in which length of day was adjusted to a constant daily level of 12 hr. 50 min. Four groups of Poll Shorthorns have been introduced into this light environment at different times during the current year. Coat changes are being observed and compared with those of control animals in the natural light environment.

Although the experiment is incomplete, the following points have emerged. The immediate changes which follow transfer to the "equatorial" light environment are well-defined and different according to the time of year (winter or summer coat) at transfer. On settling down after the transfer, the normal periodicity of the coat cycles is lost and any further changes appear to be unrelated to the seasons. After their early changes, the groups which were transferred in March and September appear to have assumed a state of simultaneous hair growth and hair loss, in which the general overall state is a woolly-coated one. The heat tolerance of both groups is the same and poor. The December and June entries are still very different, the former being short coated and sleek, the latter woolly and rough.

(*b*) *Influence of Nutritional State on Heat Tolerance in Cattle*.—An investigation, using pen fed cattle and covering observations during a three-hour heat test in a psychrometric room, showed that high condition does not in itself render cattle intolerant of heat. A high current rate of feeding, however, may add seriously to the heat load of either fat or poor cattle exposed to high temperatures.

(*c*) *Adaptation to a Tropical Environment* (Rockhampton Laboratory).—Field studies are being continued on purebred and crossbred cattle maintained at the National Cattle Breeding Station. Characters under investigation are rectal and skin temperatures, respiration rate, coat and hair characters, water vaporization from the skin, skin structure, blood constituents, and susceptibility to tick infestation. A number of methods by which coat character may be assessed have been tested; severa ave been shown to be strongly correlated with body temeratures and to be highly heritable. There is a high egree of variability among animals of British breed in oat characters and in thermoregulation. Blood contituents studied include alkaline phosphatase, creatinine, holesterol, carbon dioxide capacity, and glutathione.

8. GENETICS OF CATTLE.

Animal Genetics Section and Division of Animal Health and Production.)

(*a*) *Beef Cattle Breeding Investigations* (" Belmont " ield Station).—The breeding trials at " Belmont " Queensland) are proceeding according to plan. The ingle sire group matings in 1956 involved 14 bulls and 20 cows—six different breeds. In addition to the routine ody weight determinations for all progeny, which now otal 500 head, observations have been extended to include vorm infestations, haemoglobin and haematocrit readings, nd dentition. A preliminary survey of liver copper status as been made.

(i) *Crossbreeding Groups.*—Significant differences in ates of growth and in mean body weights are now ecoming evident between the progeny of the eight cross matings in this experiment. In general, the progeny of British breeds and cross matings between British breeds are inferior to those of Zebu and Africander bulls and British breeds. The Zebu x Shorthorn crossbreds are outstanding while the purebred Shorthorn group is least mpressive.

Data relating to susceptibility to tick (*Boophilus microplus*) and helminths are accumulating. Evidence so far suggests that Zebu and Africander crossbreds are more resistant to tick infestation than are British breeds and crosses between British breeds. Preliminary observations on haemoglobin, haematocrit, and liver copper status suggest interesting differences again in favour of the progeny of Zebu and Africander bulls and British breed females.

(ii) *Comparison between Northern-bred and Southern-bred Herefords.*—The " Belmont " section of this trial has now moved into its third year, and differences in performance between the progeny of the two groups are becoming strikingly evident. At the age of eighteen months, the northern-bred Hereford progeny are 120 lb. heavier than stock from the southern-bred Herefords, bred and raised under identical conditions. There is some evidence that this difference in performance is not entirely due to heat tolerance.

(*b*) *Observations in Central Queensland.*—Observations on skin and hair characters of *Bos taurus* have shown considerable variation in sweat gland size within strains of this species. The crossbred progeny of matings between *B. indicus* and *B. taurus* had a higher sweat gland volume than any *B. taurus* strain examined, but nevertheless did not show the highest growth rate or the greatest bodyweight under conditions prevailing in the arid area of central Queensland where the observations were made. The *B. taurus* group showing the highest growth rate also had the largest sweat gland volume.

A heat tolerance test based on exercise was devised and proved useful in practice. Observations on the effect of coat cover indicated that this factor, by itself, would not account for the whole of the difference found between *B. taurus* groups in adaptation to hot, dry conditions.

9. SWEAT GLANDS IN CATTLE.

(Animal Genetics Section.)

Work on sweat gland size continues. A new technique for preparing sections for examination which is quick has been evolved and more extensive studies of correlation between sweat gland size and other characters have been partly completed. It has been found that strains of Shorthorn show consistent differences in total sweat gland volume which are clearly due to genetic differences, though there are some slight changes with season. An extensive study of the effect of age, season, strain, and genotype on this character has started at " Belmont ". The process of hair shedding in skin sections and the state of hair follicles during the process can be used to describe events preceding and accompanying shedding. This line of work is to be expanded.

IX. ENTOMOLOGY.

1. GENERAL.

Throughout the agricultural, pastoral, and horticultural industries, Australia in common with most parts of the world suffers enormous losses from the depredations of insects. As seed, as growing crop, or as harvested food the products of the soil are continually subject to damage by insects of many thousand of species. Before a campaign against any insect can be launched with reasonable hope of success, the life history and habits of the particular species must be thoroughly investigated and understood. The Organization's investigations involving the biology and control of insect pests, the biological control of weeds, and other aspects of entomology are mainly carried out by the Division of Entomology, with head-quarters in Canberra. Collaborative work is, however, undertaken by the Division on special problems in conjunction with other laboratories. Research on insects affecting animals is done in cooperation with the Division of Animal Health and Production and is reported in Chapters VII. and VIII.; the Division plays a part in the investigations on the virus disease of rabbits being studied by the Wildlife Survey Section (*see* Chapter X., Section 2). The Division cooperates with the Division of Forest Products in the study of pests of timber (*see* Section 13 of this Chapter, and Chapter XIV., Section 6 (g)).

Division of Entomology.—Increasing emphasis is now given in the Division's work to the study of insect populations and the factors which govern the abundance of insects. These studies are being linked with the Division's ecological investigations, particularly on pasture pests such as grasshoppers, cockchafers, caterpillars, the earth mite, and the lucerne flea. With the post-war extensive development of improved pastures in many parts of Australia this work assumes increasing importance.

The Division has released a number of imported parasites of cabbage moth and cabbage butterfly and some of them are now well established. An interesting experiment in Canberra has demonstrated the need to adjust spray practice to allow these parasites to act in the field. Early in the growing season before the parasite population had built up caterpillar damage was controlled by one or two applications of lead arsenate. No subsequent sprays were applied and the parasites so effectively kept the caterpillars in check that a commercially satisfactory cabbage crop resulted. This supports the belief that the modern practice of using persistent insecticides such as DDT against insect pests often seriously interferes with the effective action of natural enemies.

Necessary preparatory work for the proposed trial locust control campaign, to be carried out in co-operation with the New South Wales Department of Agriculture, has been begun. With the appointment of a patrol officer, a survey is being made of the country in the main outbreak area, so that it will be properly mapped, and this will greatly facilitate his obtaining the necessary information to judge when an outbreak is developing.

The Division has continued to co-operate with various institutions during the year, namely, the New South Wales University of Technology on cattle dip formulations and the extraction of toxic materials from ants, the Institute of Anatomy on the biochemistry of muscle, the Australian Wheat Board, the New South Wales Flour Millers' Council, and the Department of Primary Industry on stored products pests. Co-operative work is also being done with the Victorian Department of Lands and Survey on the biological control of ragwort. The Division's method of testing various materials in laboratory colonies of termites has proved valuable to many industrial firms, particularly in the development of uses for many plastic materials.

Dr. K. H. L. Key was recently elected the Australian representative on the International Commission of Zoological Nomenclature.

2. INSECT PHYSIOLOGY AND TOXICOLOGY.

(Division of Entomology.)

(*a*) *Digestion of Wool by Insects.*—An examination is being made of factors which may be involved in the unusual degradative process which the protein of wool undergoes in wool digesting insects. An investigation of the digestibility of wool modified in various ways has begun to yield information on the mechanism of digestion by the *Tineola* proteolytic enzyme.

Some of the difficulties previously encountered in the purification of *Tineola* protease due to the presence of fatty materials and inert proteins have been reduced by the use of butanol-acetone treatment, followed by acid extraction and a controlled autolytic process. Solutions produced by this process have high specific activity. Further purification has been obtained on a small scale by adsorption and elution on a column of cationic synthetic resin.

(*b*) *Digestion of Collagen.*—An active collagenase was demonstrated in the excreta of aseptically grown blowfly larvae using a substrate (kangaroo tail tendon) rich in undenatured mature collagen. This is probably the only unequivocal demonstration of the production of a collagenase by animals, although a few bacteria are known to secrete this enzyme.

(*c*) *Digestion of Wax.*—Wax moth larvae, which are known to harbour lipolytic microorganisms in the digestive tract, remove some of the constituents of bees-wax during its passage through the gut. These larvae have now been cultured under aseptic conditions and offered a series of characteristic lipoids. They have been found capable of removing a high proportion of a C_{16} (stearic) acid, of a C_{18} (octadecyl) alcohol, and of the resultant ester (octadecyl stearate). On the other hand, relatively little of a C_{30} paraffin (*n*-triacontane) was absorbed during passage through the gut.

(*d*) *Insect Muscle Biochemistry.*—In collaboration with an officer of the Australian Institute of Anatomy, an investigation has been begun on the action of dinitro-phenol on the myosin-adenosinetriphosphatase of muscle, and the effect of various inhibitors on this system. This has yielded information of interest with regard to the biochemical and pharmacological action of dinitro-phenol and the mechanism of action of the enzyme and contractile protein, myosin.

(*e*) *Insect Cuticular Proteins.*—A study is being made of the cuticular proteins of the larvae of the longicorn beetle *Agrianome spinicollis.* Three protein fractions which represent just over 50 per cent. by weight of the entire cuticle have been isolated and are being examined.

(*f*) *Precursors of Cuticular Components.*—(i) *Changes in the Free Amino Acids of the Blood of Blowfly Larvae at Metamorphosis.*—Just prior to pupation the larval cuticle of blowflies increases considerably in thickness and during the early pupal stage becomes hardened and dark in colour. Since the blood is the reservoir for the products required for and produced by nearly every physiological activity of the insect body, changes in the free amino acids of the blood at metamorphosis may lead to an understanding of the nature of these cuticular changes.

A quantitative analysis of the free amino acids in blood from the larval, prepupal, and early pupal stages of *Calliphora augur* has therefore been performed and has demonstrated that the amino acids showing the mo marked falls in concentration at metamorphosis a alanine, glutamic acid, glutamine, glycine, proline, an tyrosine.

(ii) *Precursors of Chitin.*—Virtually nothing is know about the synthesis of chitin by insects even though it an important aspect of insect biochemistry which is n shared by higher animals. Although work on this subje is only in its early stages, it has indicated that glutamir is concerned in the biosynthesis of D-glucosamine an therefore of chitin which is built up of *N*-acetyl-D-gluc samine residues.

(*g*) *Nutrition of the Sheep Blowfly.*—A study of th food requirements for reproduction in *Lucilia cuprina* ha shown that both carbohydrate and protein are required fo egg production. Possible sources of these types of food stuffs in the field have been investigated, and the use c these sources under natural conditions by wild flies hav been verified by chemical analysis of the gut contents c trapped flies. This has shown that the excreta of shee fed on improved pasture may be an important source c free protein to flies in the field. A biochemical investiga tion of the enzymes of the crop and gut of *Lucilia* ha demonstrated that similar carbohydrases are produced both these site.

3. INSECTS AND VIRUSES.

(Division of Entomology.)

(*a*) *Insect Tissue Culture.*—Preliminary studies hav shown that previous attemps to grow insect tissues unde *in vitro* conditions failed because (1) in many instance the tissues used have not been suitable for culturing; an (2) lack of information about the chemical properties c insect blood has prevented the formulation of media c similar composition.

This investigation has therefore been divided into study of the tissues and the chemical requirements c growth. Various tissues have been cultured but it ha been found that the tissues of *Bombyx mori* (silkworm are the most suitable; they are large, easily obtainable, an the tissues increase in size by cell multiplication. Th ovaries of fifth instar larvae of *B. mori* have been used i the majority of the experiments.

Many media have been composed in an attempt t simulate the blood of each experimental insect, bu although it has been possible to keep tissues alive fo many days (a *Periplaneta americana* embryo survived fo 58 days in a chemically defined medium) no true growt has yet been obtained. During the year, a medium wa composed at the Laboratory of Insect Pathology, Sau Ste Marie, Canada, based on the analysis of the blood c the silkworm (*B. mori*), and it has been used in th laboratory with some success. Large numbers of cel migrate from tissues cultured in this medium, and surviv in a healthy condition for up to two weeks, but the growth ceases. Further work in progress involves th modification of this basic medium by the addition of vit mins, sterols, and other compounds which may promot growth.

(*b*) *Leafhopper-borne Diseases of Plants.*—Furthe studies with the wallaby ear disease have shown that may cause fodder losses in subtropical pastures. The ho range of the disease includes at least nine grasses as we as cereals, including rice and grain sorghum. The lea hopper vector was referred to the U.S.D.A. Bureau c Insect Identification in Washington, and it appears to be dfifferent species from that transmitting virus diseases t maize in other countries.

The rugose leaf curl virus disease previously tran mitted experimentally has now been recorded as serious disease in the field. It has been reported fro Queensland, New South Wales, and the Australian Capit Territory in red clover, white clover, and other legume

A disease which affected large areas of subterranean clover in New South Wales during the autumn of 1955 was investigated with the co-operation of officers of the New South Wales Department of Agriculture. Tests in the insectary showed that an aphid-borne virus was causing part of the trouble, but in some areas the leaf-hopper-borne lucerne witches' broom virus was also present. In addition, it is highly probable that the field picture was further confused by the effect of insect toxins.

4. Population Dynamics.

(Division of Entomology.)

(*a*) *Laboratory Studies.*—The long-range experiments with cultures of *Lucilia cuprina* subjected to periodically fluctuating environments have been continued. A wide range of periods of environmental fluctuation were used and it was found that in each culture there was a strong tendency for the oscillations in population density to take over the period of environmental fluctuation, or some definite multiple of this. It was further demonstrated that the main cause of the violence of population change was the delay in the effects of competition within the cultures. This illustrates and supports the contention that, although fluctuations in the abundance of animals living under natural conditions can often be correlated in time with periodic climatic changes, this correlation does not prove that climate determines abundance, or even the degree of change in abundance. As in the *Lucilia* cultures, periodic environmental change may simply provide part of the framework within which the population automatically adjusts its density to the prevailing conditions by density induced variations in the intensity of competition for the essential requirements of the individuals, or in the intensity of predation, parasitism, or disease.

(*b*) *Field Studies.*—Outbreaks of three psyllid species of the genus *Cardiaspina* are continuing to damage eucalypts in parts of the Canberra district. The species attacking *Eucalyptus blakelyi* is destroying an increasing number of trees. In the areas of outbreak, *Cardiaspina* spp. are causing a progressive decrease in the amount of eucalypt foliage present, i.e. in the supply of food and favorable space available to them, and thereby are slowly becoming less numerous.

In much of the district, where *Cardiaspina* numbers are relatively low but increasing progressively, no density governing factors have been observed since work began three years ago. Elsewhere numbers have fluctuated at very low levels of population density. Field experiments in one such area of very low numbers suggest that the species of *Cardiaspina* which feeds on *E. blakelyi* is under density governance there by a species of encyrtid parasite.

The evidence from other study areas, where *Cardiaspina* is much more numerous, indicates that this parasite and other encyrtids have not been effective in density regulation partly because of poor synchronization between host occurrence and parasite attack and partly because of hyperparasites.

5. Locusts and Grasshoppers.

(Division of Entomology.)

(*a*) *The Australian Plague Locust.*—Testing of the effect of the shrub-planting treatment in selected outbreak centres of the Australian plague locust has been continued in the Bogan-Macquarie outbreak area. This treatment is designed to reduce the favorability of the outbreak centres for locust multiplication and swarm formation, and constitutes a small-scale trial of the control strategy of " outbreak prevention ". In previous years the assessment of the effect of the treatment on locust density was complicated by the presence of migrating swarms and by unexpected shifts in the distribution of even the non-swarming population. During 1955-56, very high local rainfall, together with widespread flooding, kept the population consistently at a low level, but also interfered with access to a number of the test areas. In spite of the relatively low densities, migration was again a complicating factor. It is beginning to appear as though a sedentary population is the exception rather than the rule, even when swarms are absent.

Preparatory work was continued in connexion with the projected Commonwealth-State trial of the control strategy of " outbreak suppression ". A patrol officer has been appointed by the New South Wales Department of Agriculture to keep in touch with locust developments in the Bogan-Macquarie and other outbreak areas and to ascertain when dangerous densities are developing. At present he is familiarizing himself with the terrain and carrying out a survey, in co-operation with C.S.I.R.O., to locate the outbreak centres where at a later stage swarms may be expected to arise.

(*b*) *Solitary Grasshoppers.*—Field and laboratory work has continued on *Phaulacridium vittatum*, *Brachyexarna* sp., and *Austroicetes pusilla*, though *Phaulacridium* being the most abundant was singled out for intensive study. During the summer of 1955-56 large populations of *Phaulacridium* in the Australian Capital Territory occurred only in improved pastures. At a site consisting of improved pasture near Hall, Australian Capital Territory, intensive studies were made of the survival of nymphs, the hatching of eggs, and the dispersal of the fully-winged and short-winged forms of *Phaulacridium*.

The unusually heavy rains in summer caused an early decline in the numbers of most species of grasshoppers in the Australian Capital Territory and surrounding parts of New South Wales. This was at least partly due to fungal diseases, parasites being relatively unimportant. High soil moisture caused by rain-inhibited egg laying by surviving females of *Phaulacridium* though ample food was available for the maturation of large numbers of eggs.

A cytotaxonomic study on a group of species of *Austroicetes* has recently been completed in collaboration with a cytologist in the Division of Plant Industry. It has demonstrated the existence of a distinct species that would have remained unrecognizable without a cytological analysis. A cytotaxonomic revision of the peculiar group of grasshoppers known as the Morabinae is also in progress.

6. Pasture Cockchafers.

(Division of Entomology.)

(*a*) *The Black Beetle.*—The decline in numbers of the black beetle (*Heteronychus sanctae-helenae*) continued during the present year, and in field trial plots that have been under regular observation, the species is present only at extremely low densities. Continuance of low population densities is attributed to the abnormally wet season; very moist soil conditions appear to increase the susceptibility of all stages of the insect to bacterial and fungal diseases.

(*b*) *The Pruinose Scarab.*—This species (*Sericesthis pruinosa*) is a pest of turf and pastures in the coastal districts in eastern Australia. Extensive trials were carried out, using several of the newer insecticides. Aldrin proved to be oustanding for the control of the larval stages in turf. Under average conditions, 1 lb. of aldrin per acre, applied as 1: 1000 spray, gave a virtually complete control within seven days of treatment. Treatment was most effective when applied early in the season, as soon as infestations became apparent. Experiments have shown that not only does the effectiveness of the insecticide decrease as soil temperatures decline in early winter, but that when the larvae have entered their third and final growth stage, they rapidly acquire a marked resistance to it.

(*c*) *Christmas Beetles.*—These insects (*Anoplognathus* spp.) are the cause of severe defoliation of many species of eucalypts. They were extremely abundant during the past summer and some earlier studies on their biology and host preferences were resumed.

The nomenclature and classification of these beetles was found to be in a very confused state, some species being variously known under as many as six different names. A revision of the genus was carried out which will enable each species to be correctly identified and known under a single appropriate name. Stabilization of this kind is essential to ensure the validity of observations on the biology and ecology of the various species.

7. PASTURE CATERPILLARS.

(Division of Entomology.)

Investigations have been continued on the distribution, ecology, and pest status of Australian cutworms and armyworms, many of which cause serious damage to pastures and field crops. Attacks occur at irregular intervals and observations show that in some seasons populations of several quite unrelated species are liable to reach pest proportions simultaneously. Though insecticidal control of these pests is often satisfactory, practical difficulties arise in applying sprays effectively. The study of the ecology of these pests is therefore designed to improve our knowledge of the factors which determine the seasonal distribution of the moths, the choice of host plants, and the number of eggs laid, as well as those factors which favour larval, pupal, and moth survival. When this information is available it should be possible to forecast attacks so as to enable landholders to apply insecticides, perhaps on a much reduced scale, before serious damage is caused.

Observations and experiments on *Agrotis infusa* have continued during the year. Very high populations of aestivating moths, similar to those recorded in the 1952-53 summer, were again present at Mount Gingera, Australian Capital Territory. On both occasions larval populations were very high in the preceding winter and spring, causing economic losses in some areas. An experimental study of the factors which influence migration and adult diapause in this species is in progress.

8. RED-LEGGED EARTH MITE AND LUCERNE FLEA.

(Division of Entomology.)

(*a*) *Insecticide Experiments.*—Experiments during 1955 resulted in a change in the recommendation for treatment against these pests. It has now been shown that a mixture of malathion and DDT at rates of ½ oz. plus 1 oz. active ingredient per acre respectively will achieve a good control of both pests. Residual action against the lucerne flea is negligible but the DDT will ensure some residual control of the earth mite. The toxicity of this mixture to mammals is very low and the cost is also considerably lower than the previously recommended mixture of parathion and DDT. In view of these results tests with contact insecticides have now been discontinued.

Preliminary pot trials with several systemic insecticides indicate that soaking the seed of subterranean clover in some of these materials will give rise to seedlings toxic to the earth mite.

(*b*) *Population Studies.*—A preliminary analysis of the results of three years' observations on two selected areas of pasture has yielded some interesting information on the regulation of population density in both the lucerne flea and the red-legged earth mite. Local populations which are dense at the beginning of the season have declined rapidly at the end of the season or the beginning of the following season, and initially sparse populations have increased equally rapidly. Populations over large areas are thus made up of a great number of local populations, some of which are declining and some increasing. There are also indications, particularly from experiments usir specific insecticides, that, as well as intraspecific compet tion within each species, there is interspecific competitic for some requisite between the earth mite and the lucerr flea.

A comparison of the two study areas suggests that th effect of the predatory bdellid mites on the lucerne fle is to increase the rate of decline of a population and t delay the subsequent build-up.

(*c*) *Physiological Studies.*—Further studies of th winter and over-summering eggs of the red-legged eart mite have shown that the special over-summering egg are developed as a result chiefly of rising temperature in the spring. The maintenance of adequate moisture an short day-length failed to prevent or delay the develop ment of these eggs in the field. Consequently, the appear at an earlier date in the warmer areas than in th cooler areas of Western Australia. These eggs canno resume normal development, even when adequate moistur is supplied, until they have received a period of exposur to high temperatures, the period required being shorte at between 60 and 70° C.

9. CATTLE TICK.

(Division of Entomology.)

This work is reported in Chapter VIII., Section 5.

10. SHEEP BLOWFLY.

(Division of Entomology.)

This work is reported in Chapter VII., Section 21.

11. INSECT PESTS OF STORED PRODUCTS.

(Division of Entomology.)

Further investigations into air-tight storage of grain hav been carried out. In the laboratory a study of the effect of the method on the large strain of the rice weevi *Calandra oryzae* has been made.

In the field the practicability of applying the principle t existing country silos has been examined. As the sealin of the interior surface of the bin walls would be a costl operation, the effects of sealing the top and bottom onl of a bin have been examined. With the co-operation o the New South Wales Grain Elevators Board, a small bi in a country silo was selected, and, after sealing the oper mouth and the hopper, the diffusion rate of oxygen throug the concrete walls was measured. Full results are not ye known but it appears possible that simple sealing of thi nature may serve a useful purpose, especially as the vas majority of existing silo bins are of much larger capacit and thus possess more favorable volume to surface ratios

During the year the Division's assistance was sought b the Department of Primary Industry and the new Sout Wales Flour Millers' Council, owing to the incidence o insect infestation on bags of export flour. Insect pest were causing rejection of the flour at Australian ports o loading as well as complaints from overseas markets. A investigation is in progress to determine the source of th insects. The wheat, the flour mills, the bags, and the transport involved are all possible sources and all are bein examined.

12. BIOLOGICAL CONTROL.

(Division of Entomology.)

(*a*) *Weed Problems.*—(i) *St. John's Wort* (Hypericum perforatum).—Further distributions of the chrysomeli beetles, mainly *Chrysomela quadrigemina,* were made i several districts of New South Wales. The areas concerne were mostly in the southern half of the State, but one wa as far north as Kootingal.

A new liberation of the gall-fly *Zeuxidiplosis giardi* wa made at Garland, New South Wales. Colonies at Myrtleford and Bright in Victoria, liberated in 1954 and 195 respectively, are making satisfactory progress.

(ii) *Ragwort* (Senecio jacobaea).—During the year an troduction of *Euchelia* (*Tyria*) *jacobaeae* was made from ngland and Italy to combat this weed in the Gippsland d Otway areas of Victoria. Some success was obtained overcoming diapause in the introduced pupae by exposg them to low temperatures.

During the flowering season of ragwort, all stages of *jacobaeae* were liberated in Gippsland. Field studies ere made on the insect's biology, its acclimatization, and tive enemies. In spite of high mortality of the larvae the field from wilt and fungal disease, several thousands ached the pupal stage, thus securing a colony for the ming season.

(iii) *Lantana* (Lantana camara).—Food tests on a imber of lantana insects are being carried out in Hawaii the Department of Public Lands of Queensland in nsultation with C.S.I.R.O. The project is jointly financed the Department and C.S.I.R.O.

(*b*) *Insect Problems*.—(i) *Pests of Crucifers*.—At the ickson Experiment Farm during the last two years, cabges grown on experimental plots without the use of any secticides suffered little damage from *Plutella* or *Pieris* d, when mature, receive quite satisfactory ratings for arketability. During the last year, cabbage crops grown the Farm received either no insecticidal treatment, or e or more applications of lead arsenate. Nearly all ots provided a high proportion of sound marketable bbages, but one or two applications of lead arsenate iring the growth of the crop helped to reduce insect image to a low level. No insecticidal treatment was oplied for *Brevicoryne brassicae,* which caused no signicant damage although it is generally a serious pest of ucifers. It appears that the absence of persistent insectides (such as DDT) on these plots has permitted the parae *Diaeretus rapae* and other natural enemies to control is aphid very efficiently.

(ii) *Green Vegetable Bug* (Nezara viridula).—*Microianurus basalis* (West Indian strain) and *Ooencyrtus ıbmetallicus* continued to be liberated widely in collaboraon with the Departments of Agriculture of most of the ainland States. A study has been made of the effects of ompetition for hosts between *M. basalis* and *O. submetalcus*. Further investigations have been made into the tent of parasitism of the eggs of *Nezara viridula,* and e status of the native parasites bred from the eggs.

(iii) *Brown Vegetable Weevil* (Listroderes obliquus).—reliminary work has begun with this species.

(iv) *Queensland Fruit Fly* (Strumeta tryoni).—The apping of adult fruit flies and the collection of fruit mples from areas where insecticides are not used was panded during the year, the object being to increase the ficiency of assessing the effect of introduced parasites ter on. The greatest activity occurred from early nuary to late April. Sampling results confirm that fruit populations are virtually unaffected by endoparasitic incts and that the native *Opius tryoni* is practically the only uit fly parasite present.

For the first time, small numbers of *Opius longicaudatus* mported from Hawaii in 1953) which lays its eggs in ell-grown fruit fly larvae, were liberated in the Sydney ea. Some recoveries were made but it cannot yet be said at the species is established. Another parasite, *O. ophilus,* which lays its eggs in the fruit fly eggs, is difficult rear in the laboratory, but the technique has been imoved and for the first time the species has been bred rough in the laboratory from flies received from Hawaii rly in 1956.

(v) *Wax Scales*.—A consignment of *Anicetus beneficus,* effective enemy of pink wax scale (*C. rubens*), has been ceived from Japan for experimental purposes, but it did ot prove possible to establish a culture of these wasps. he establishment of host plants and colonies of pink wax ale and white wax scale (*C. destructor*) is in progress, reparatory to the introduction of parasites.

(vi) *Aphid Parasite and Predator Studies*.—The evaluation of the aphid fauna of Australia (there are about 80 species recorded) and of their insect parasites and predators has been continued. The efficiency of the many primary parasites present is seriously impaired by the presence of hyperparasites belonging to the Cynipoidea, Chalcidoidea, and Proctotrupoidea. There are several predators of some importance.

13. Termites and other Wood-destroying Insects.

(Division of Entomology.)

(*a*) *Termite Investigations*.—The standard laboratory testing technique using colonies of either *Nasutitermes exitiosus* or *Coptotermes lacteus* has been used to determine the termite resistance of a variety of materials. Interim results on the third group of commercial timbers indicate that these timbers may be arranged in the following order of decreasing resistance: *Eucalyptus rostrata, E. propinqua, E. punctata, E. saligna, E. eugenioides, E. sieberiana.* Plastics which appear to have a high resistance to termite attack include polystyrene, unsaturated polyesters, epoxylines, and phenolic laminates. Plastics such as polyvinyl chloride and cellulose acetate, although resistant in the rigid and unplasticized condition, become susceptible when plasticized. New field tests installed during the year included a series of samples of polythene and polyvinyl chloride containing small quantities of insecticides such as aldrin, dieldrin, and lindane.

Observations have been continued on soil treatments for termite control. Against *N. exitiosus* near Canberra and *Coptotermes frenchi, Heterotermes ferox,* and *Microcerotermes* sp. in the Riverina, DDT, chlordane, creosote, and pentachlorphenol have all given complete protection so far for periods varying between two and six years. In conjunction with officers of the Wildlife Survey Section, a second survey was made to complete the study of the distribution, biology, and economic importance of the genus *Coptotermes* in south-western Australia.

(*b*) *Termites in Forest Trees*.—The termite *Porotermes adamsoni* is a major pest of commercial hardwood forests in the alpine regions of New South Wales and Victoria. Studies of the root systems of six infested trees, felled for mill logs, showed that 48 of the 90 large roots radiating from the stumps contained termite galleries. The termites made galleries in and adjacent to the roots for distances of up to 29 feet from the stump. The galleries outside the roots were associated with moist ground, and no evidence was obtained that this termite obtained an entry into trees via the roots or spread from tree to tree by this means.

(*c*) Lyctus *Investigations*.—In co-operation with the Division of Forest Products and the Queensland Forest Service a second survey is being conducted on the susceptibility to *Lyctus* attack of a number of Queensland timbers.

In co-operation with the Division of Forest Products a study is in progress on the relative efficiency and persistence of various surface treatments for the prevention of *Lyctus* attack. All treatments were effective immediately on application, and are now being tested again after six months' indoor weathering.

14. Ant Investigations.

(Division of Entomology.)

(*a*) *Meat Ants*.—A large-scale experiment was set up in November, 1954, to compare the more promising insecticides for the control of meat ant colonies, and to study the persistence of these insecticides in preventing ants from neighbouring colonies from occupying the treated nest sites.

Fourteen months after treatment dusts and sprays containing dieldrin and chlordane have been found completely effective.

(*b*) *Argentine Ant.*—The eradication campaign in Sydney, in co-operation with the New South Wales Department of Agriculture and local government bodies, was continued during the year. All known infestations were treated before the summer months, but, resulting from public co-operation in a reward system for locating new infestations, a total of 40 new infestations were discovered during late summer. Infestations were found for the first time on the north side of the Parramatta River at Manly and Rydalmere. All new areas were under 20 acres.

In a check survey during February-April, 1956, 45 out of 51 treated areas were free of ants. Most colonies formed were small and the occurrence of odd colonies of ants in treated areas is receiving special attention.

In Victoria an experiment just concluded has shown that sprays containing 0.5 per cent. dieldrin or 2 per cent. chlordane are just as effective under Victorian conditions as they have proved to be in Perth and Sydney.

15. INSECTICIDE INVESTIGATIONS.

(Division of Entomology.)

Strains of house flies which had previously been shown to be resistant to DDT, as a result of selection with DDT or for slow rate of pre-adult development, have shown little or no evidence of resistance to BHC, diazinon, allethrin, and sodium arsenite. It has been demonstrated that the DDT-synergist, DMC, potentiates the action of DDT on all of the resistant strains examined. This suggests that the strains have a common mechanism of resistance, namely, the ability to detoxify DDT enzymatically, but preliminary attempts to demonstrate the presence of a dehydrochlorinating enzyme were inconclusive.

An examination was carried out on the insecticidal activity of a series of seven chelated metal salts (complex ions) prepared at the Chemistry School of the University of Sydney. These compounds covered a range of ionic charge, water and lipid solubility, and *in vitro* action on mammalian enzymes, but although in experiments by the Division of Animal Health and Production some of them had proved highly toxic when injected interperitoneally into mammals, all were found to be low in toxicity to insects treated either externally or by injection.

Some progress has been made with insecticidal tests on compounds extracted from various species of ants of the genus *Iridomyrmex*. The extraction and chemical identifications of these compounds is being investigated by the School of Applied Chemistry of the New South Wales University of Technology.

16. TAXONOMY.

(Division of Entomology.)

A simple request for the identification of an insect specimen frequently causes considerable embarrassment to an Australian taxonomist. When he examines the collections available to him he may find that there are no named specimens of the species concerned. A search of the literature still leaves him in doubt and even if he can tentatively suggest a species he cannot easily confirm it because the type of that species is probably in a European museum. Almost invariably he is forced to the conclusion that the whole group, perhaps a whole family, needs thorough study before anybody can identify any species in it with certainty.

All of those whose work is in the field of insect ecology encounter this problem sooner or later. In order to establish which insects they are studying, they must endeavour to find specialists somewhere in the world who will undertake revisions of their groups, or else they must do the work themselves, usually as a sideline to their main project. Often they find the task far greater than they expected and so the sideline tends to absorb more and more time.

Some of the ecologists in the Division are more fortunate than others in that there are workers elsewhere wh will undertake the necessary revision for them: fo example, the grasshoppers are being studied by a American taxonomist; the parasitic wasps of the Braconidae and Ichneumonidae by a New Zealander; the leafhoppers transmitting plant viruses by another America and an Australian; the bdellid mites, predators of the red legged earth mite, by a taxonomist in Adelaide; and th ants by Australian and American specialists. Within th Division, however, taxonomic studies are being made o certain of the scarabaeoidea (the Dynastine and th Christmas beetles) in connexion with ecological work o cockchafers affecting pastures and trees; the termites; th Tortricidae (a family of moths which includes man important pests); and *Agrotis* spp. (cutworms of pasture and field crops). Two officers are working almost ful time on two large and very important groups, viz. th Diptera (flies) and the Chalcidoidea, which is the majo group of parasitic wasps.

Three valuable entomological collections were acquire by the Division during the year. These were the extensiv collection of New Guinea butterflies and moths, given t the Commonwealth Government by Sir Edwar Hallstrom; the moth collection of the late Commande L. H. Mosse-Robinson (donated by his wife); and the an collection of the late Mr. John Clark, who was the Australian authority on this group.

X. WILDLIFE.

1. GENERAL.

In every country in the world mammals and birds, bot native and introduced, affect primary production an other human activities in a variety of ways. In Australia what may conveniently be termed wildlife problems rang from that of the rabbit, the country's most serious pest to the mutton bird, on which a small but valuable loca industry depends. Kangaroos, possums, and wild duck and geese of various species may be pests at various time and in parts of their range, while calling for conservatio elsewhere because of their economic value or thei importance as game. To deal with wildlife problems tha called urgently for solution or merited scientific study fo other reasons, the Organization established its Wildlif Survey Section in 1949.

In many of its investigations the Section depend materially on collaboration with State Departments, wit Universities (particularly the Australian National University), and with other branches of the Organization, whil most of its field work would be impossible without th assistance of individual land-holders.

Wildlife Survey Section.—The Section has establishe close relations with the Antarctic Division of the Department of External Affairs, and has taken on a consultan and advisory role in connexion with the biological researc carried out by the Australian National Antarctic Researc Expeditions. A member of the Section's staff has bee seconded to the Antarctic Division to carry out biologica observations at Macquarie Island during 1956.

2. RABBIT INVESTIGATIONS.

(Wildlife Survey Section.)

(*a*) *Myxomatosis.*—Very few spectacular and widespread outbreaks of myxomatosis have been reporte during 1955-56, but many areas in south-eastern Australi have now experienced five successive outbreaks of th disease and the general level of rabbit populations appea to be remaining very low.

The investigations fall into three main categories—

(i) regional surveys carried out to assess the seasonal performance of the disease and to collect information that might explain the local variations;

(ii) intensive investigations into the ecology and behaviour of insect vectors;

(iii) work on variant strains of the disease.

Detailed observations on the epidemiology of myxonatosis have been continued in four regions: the Mallee nd Wimmera districts of north-western Victoria; and in Vew South Wales, the eastern Riverina area, the New Ingland Tableland in the north, and the South Coast-outhern Tablelands area. Studies in these regions ndicate that generally the amount and distribution of ainfall are closely correlated with the development of nyxomatosis epidemics. These investigations are providng useful data for planning tactical field inoculations with irus.

In north-western Victoria *Anopheles annulipes, Culex ipiens australicus,* and *Culex annulirostris* are the mportant mosquito vectors. In dry years the dams for tock and domestic water supply throughout this area rovide the main vector breeding areas, and these reach heir peak production in January, so that in such years noculation of rabbits should take place in early January; vhereas, in wet years, when vectors are being produced n natural water-filled depressions, inoculation will produce he best overall result if carried out in early to mid-Jctober.

In the eastern Riverina, studies in three areas to explain he differences in disease performance from season to eason and habitat to habitat have been concluded. Here gain these differences are a reflection of the response f the habitats and vectors to rainfall distribution. The nosquitoes *A. annulipes* and *C. annulirostris* are the mportant vectors, their relative importance varying ccording to the season. In the eastern Riverina there ave been annual outbreaks of myxomatosis since 1951, nd it seems likely that only under very dry conditions will nyxomatosis fail to cause appreciable mortality amongst abbits.

On the New England Tableland, a close correlation etween the development of vector populations and the easonal rainfall has been observed. Intensive studies in hree areas on the tableland ranging from 2,500 to ,000 ft. altitude are designed to determine how such lifferences affect vector abundance and activity.

In the South Coast-Southern Tablelands area of New outh Wales investigations have been continued at Merriumbene and Colo Vale. At these centres the vector icture is much less clear-cut than in the Riverina country o the west. During 1954-55 and 1955-56 the peak of he myxomatosis epidemic occurred in early autumn, even lthough seasonal conditions, rabbit density, and mosquito opulations were markedly different. This phenomenon f regular autumn incidence is being investigated in o-operation with entomologists from the School of Public Iealth and Tropical Medicine, Sydney. Advice and o-operation have also been provided by the Division of Aeteorological Physics, Commonwealth Scientific and ndustrial Research Organization.

The development of rabbits genetically resistant to nyxomatosis has been observed in a series of tests for vhich material was supplied to the Department of Microiology, Australian National University. After each vearly outbreak of the disease at Lake Urana, kitten orogeny of the surviving rabbits have been caught, reared o four months in the laboratory, and challenged with a tandard dose of virus. There has been a marked fall in he mortality rate and observations are being continued.

The " interference " of one strain of myxomatosis with another was studied in wild rabbits under laboratory conlitions. Several combinations of highly virulent and attenuated strains were tested. Results to date suggest that protection from virulent strains by prior or simultaneous inoculation with an attenuated strain is due to the earlier production of antibody by the less virulent strain, but further tests will be carried out to exclude other possibilities. Laboratory-bred rabbits will be used, as genetic variations in the resistance of populations of wild rabbits after successive myxomatosis epidemics preclude the standardizing of tests.

(*b*) *Rabbit Biology and Ecology*.—A small trial was carried out to see whether discrete rabbit populations could be maintained, handled, and sampled under reasonably natural conditions in small enclosures. This appears to be possible and opens the way for experimental manipulation of populations, especially that designed to measure the population response to control measures of various kinds.

An investigation of rabbit breeding in three climatically dissimilar areas in New South Wales has continued, and an analysis of the data in relation to environmental factors is now being made. Parallel observations on rabbit breeding seasons in the very different climatic setting of Macquarie Island are being made by the member of the Section working there.

In co-operation with the Tasmanian Department of Agriculture a survey has been commenced in a district in the north-east of the State to assess for a number of properties the long-term effect on rabbit populations and productivity of the control methods used in that area. At present these are based on the large-scale use of " 1080 " poison.

3. KANGAROO INVESTIGATIONS.

(Wildlife Survey Section.)

This work is being done at the Woodstock Field Station, situated between Port Hedland and Marble Bar in north-western Australia. In this area the hill kangaroo or euro (*Macropus robustus*) is a serious problem. The biological investigations are designed to provide a basis for an improved strategy of control.

Movements and drinking habits have been studied to obtain data essential for the success of a control campaign using poisoned water. Euros were narcotized after drinking a weak solution of chloral hydrate, and were individually marked with plastic collars carrying combinations of symbols cut from reflective tape. By using a spotlight and binoculars the animals could be observed at night.

Attempts have been made to estimate euro density by regular sight counts, and by using automatic counters, mostly mechanical, at watering places. One electrical counter recorded the time and date when a kangaroo drank, while an electronic device detected all kangaroos passing close to an antenna as they went to water.

4. MARSUPIAL SURVEY, NEW SOUTH WALES.

(Wildlife Survey Section.)

A survey of the distribution and abundance of marsupials in New South Wales has been undertaken. The information will be of assistance in planning the control of pest species and will also indicate a course of action to conserve the rarer species. Results to date indicate extensions of the known range of some species, while a great shrinkage has been noticed in the range of the rarer species.

5. QUOKKA STUDIES.

(Wildlife Survey Section.)

The study of the population of the quokka, *Setonix brachyurus,* on Rottnest Island, Western Australia, continued. During winter more than 700 quokkas were caught and marked, over as wide an area of the island as possible, in the hope that they would be picked up in the following summer at the focal points provided by several soaks where long-net sampling and census taking were tried. Preliminary analyses indicate that this sampling technique can be applied to census quokkas.

Nearly 2,500 quokkas have been individually marked and have been recaptured a total of 4,000 times. Routine data have been obtained on breeding, growth, and condition, and a study was made of drinking behaviour at the soaks.

6. Bird Banding.

(Wildlife Survey Section.)

The number of banders now enrolled is 49 and the scale of operations has increased considerably. The total of nearly 9,907 birds banded during the past year includes 4,500 silver gulls, *Larus novae-hollandiae,* and 1,750 crested terns, *Sterna bergii*—a co-operative effort by members of the Section and amateur ornithologists. Public interest in this study is shown by the fact that more than 50 gull bands have been returned, as well as useful observations made of colour-banded birds. Banding has played an important part in ibis and duck investigations.

At Macquarie Island, members of the Australian National Antarctic Research Expedition have banded 1,030 birds. The most interesting recoveries have been young giant petrels, *Macronectes giganteus,* which have reached Australia, New Zealand, South Africa, and Chile.

7. Wild Duck Investigations.

(Wildlife Survey Section.)

The study of the economics of wild ducks in irrigation areas of New South Wales was completed, with the general conclusion that wild ducks, on the whole, are very minor pests of rice-growing. Damage is done only in exceptional years and then it is usually slight. The maned goose or wood duck, *Chenonetta jubata,* is more capable of damaging crops than the river ducks, but even this species, in most years, is not a serious hazard to growers. Studies of the feeding habits of wild ducks in much of inland New South Wales were concluded and are being prepared for publication. The breeding cycle of the birds was also studied, and the evidence suggests that breeding is directly stimulated by a rising water level in the rivers.

8. Magpie Goose Investigations.

(Wildlife Survey Section.)

At the request of the Department of Territories a study of the magpie goose, *Anseranas semipalmata,* in the Northern Territory was initiated and the area visited four times. The aim of the work is to study the goose in relation to its possible effect on the development of rice-growing in the area.

9. Mutton-bird Investigations.

(Wildlife Survey Section.)

The joint investigations with the Tasmania Animals and Birds Protection Board of the economic biology of the mutton-bird, *Puffinus tenuirostris,* in the Furneaux Group, Bass Strait, comprised two periods of field work, in November-December and in March.

At Fisher Island the discovery was made of a breeding bird which had been born on the island six years previously. This is the first record of the breeding of a bird reared on the island, although many such birds, including this one, have been recorded in previous years on Fisher Island as non-breeding prospectors. It thus appears that this species has a lengthy period of immaturity. During the year, three birds banded as fledglings in the Furneaux Group in 1955 were recovered outside the breeding area —two in the north Pacific and the other in New South Wales. These recoveries will help to develop the picture of the bird's migratory routes and habits.

In the " Lincoln Index " studies, designed to assess the effect of commercial harvesting on the mutton-bird population, 1,350 young birds were banded on the commercial islands before the season opened. This was considerably less than in previous years and was due to heavy unseasonal summer rains which had a catastrophic effect on the breeding success on all but one of the commercial islands.

10. Ibis Investigations.

(Wildlife Survey Section.)

The study of breeding in relation to weather, water conditions, and food has continued. The unusually wet year has demonstrated the ability of ibises to breed at all seasons, and nesting has been in progress, with hardly a break, somewhere in southern Queensland, throughout New South Wales, or along the Murray. The onset of breeding is stimulated mainly by changes of flood-water level, clearly shown in south-western Queensland when local rains were not involved, rather than by other weather factors or even by increased food supply. Other aspects of breeding, such as parent-young relationships and feeding of young, received some attention.

The first stage in the analysis of food samples has been completed. Insects and other pests feature more prominently in the food of the straw-necked ibis, *Threskiornis spinicollis,* than in the white ibis, *T. molucca,* which prefers aquatic material. A consideration of the relative numbers and distribution of ibises in relation to grasshoppers leads to the conclusion that their value in controlling swarms must be negligible.

11. Magpie Study.

(Wildlife Survey Section.)

The search for a species of bird which would lend itself to a long-term study of the factors regulating population density focused finally on the black-backed magpie, *Gymnorhina tibicen.* An area of almost 5 square miles was mapped in detail, and half of this, centring on Gungahlin, the Section's head-quarters, is the area of intensive study where most (124 out of 142) resident magpies have been colour-banded and are counted every two months or so. All 87 nestlings in the area were banded during the 1955 season, and much breeding data collected.

The social organization of this species, throughout the year with no alteration during breeding, into strictly territorial groups of two to eight individuals of varying age/ sex distribution is now clear. Its sedentary habit is wel established, even in the case of young birds which remain one or two years, possibly sometimes permanently, with their parents in the territory of their birth. The suitable habitat with adequate tree cover and other requirement is parcelled completely into territories, but open country is occupied by large non-breeding flocks which also appea to be relatively sedentary.

Weather data and habitat changes are being recorded and samples of food taken by magpies are collected, to determine which biological and physical factors meri close attention as being important in population regulation

XI. UNDERDEVELOPED REGIONS.

1. General.

The normal processes of exploration and pioneer occupation have resulted in the rural settlement of mos accessible and easily developed parts of Australia. Ther are, however, large portions of the continent and th Territories which are underdeveloped or only very sparsel occupied, by reason of low rainfall, poor soils, spars pastures, inadequate water, and great distances from centres of dense population.

It is essential to understand the problems of these areas and where possible to solve them, so that either new developments can take place or the present level of production can be protected from unwise exploitation.

In 1946, the former Council for Scientific and Industrial Research was requested to initiate a series of land surveys of underdeveloped regions in order that the development potential might be more accurately assessed. In consequence, the Northern Australian Regional Survey, established and expanded later as the Organization's Land Research and Regional Survey Section, was organized to conduct these regional surveys.

Whilst the work of the Land Research and Regional Survey Section is thus concerned with the sparsely populated arid and semi-arid regions of the continent, much complementary work is carried out by other Divisions of the Organization on the development of low-producing areas in the less isolated regions. The Division of Biochemistry and General Nutrition is investigating problems of plant and animal nutrition on the Coonalpyn Downs in South Australia (*see* Chapter VI., Section 11), the Division of Animal Health and Production is breeding cattle at "Belmont", Rockhampton, Queensland (*see* Chapter V., Section 9), the Plant and Soils Laboratory is studying the wallum country in eastern Queensland (*see* Chapter III., Section 21), and the Division of Soils is making soil surveys throughout the Commonwealth (*see* Chapter II.). Allied work is also carried out by the Division of Plant Industry on plant and pasture ecology at Trangie, New South Wales, south-eastern Queensland, and elsewhere (*see* Chapter III.).

Land Research and Regional Survey Section.—The Section has its head-quarters at Canberra and field stations at Katherine, Northern Territory, Ivanhoe (Kimberley, Western Australia), and Alice Springs, Northern Territory. The Section is concerned with: (1) the survey and mapping of large underdeveloped regions and the primary assessment of land-use potential; (2) research into problems of agricultural and pastoral development in selected portions of those regions; (3) climatological studies; and (4) research into land-use problems of the arid and semi-arid zones of Australia.

In addition to these specific fields of research, the Section is closely associated by representation on technical committees with experiments with rice-growing and other projects in the Northern Territory and with tropical pasture work in Queensland.

An officer of the Climatology Unit spent most of the year overseas. Part of this time was spent visiting climatology research centres in various countries and part working at the University of Nottingham and at Duke University, North Carolina.

The Officer-in-charge of the Section was absent in 1955 on a six months' tour overseas. The primary purpose of the visit was to study arid land problems in the United States but opportunity was also taken to visit mechanized rice development schemes in British Guiana and Surinam and also to recruit staff in the United Kingdom, Holland, and Germany. Visits were also made to arid areas of Israel and Pakistan. He later paid a brief visit to Syria at the invitation of U.N.E.S.C.O. Arid Zone Committee to advise U.N.E.S.C.O. and the Syrian authorities on the organization of an integrated pilot survey of an arid area along the lines developed by the Section.

During August the Mainland Survey Unit conducted a special tour of arid zone areas for Professor F. W. Went, a visiting plant physiologist from the Earhart Laboratories, California Institute of Technology, and officers of the Division of Plant Industry. The tour commenced at Rockhampton Downs on the Barkly Tableland and ended at Oodnadatta in South Australia. It thus traversed from the summer rainfall area through the central area of unreliable or erratic rainfall to the winter rainfall area. A short visit was made to the edge of the Simpson Desert.

In his capacity of Arid Zone Research Liaison Officer, the Officer-in-charge of the Section visited the Wiluna-Meekatharra area in November with an officer of the Division of Plant Industry and officers of the Western Australian Department of Agriculture, and reported on the area and its problems. The visit arose from a request by the Director of Agriculture, Western Australia, for C.S.I.R.O. participation in research activities in the Murchison area, with the possibility of a co-operative centre at Wiluna. It was recommended that a comprehensive survey should be conducted by the Section and that following the survey new ecological and hydrological studies should be initiated.

2. REGIONAL SURVEYS.

(Land Research and Regional Survey Section.)

The two regional survey units of the section have continued operations, one on the mainland of Australia and one in the Territories of Papua and New Guinea. The first unit has been in operation in northern Australia since 1946 and has completed surveys of the following areas: Katherine-Darwin (27,000 square miles), Barkly (120,000 square miles), Townsville-Bowen (6,000 square miles), Ord-Victoria (70,000 square miles), Leichhardt-Gilbert (110,000 square miles), North Kimberley (34,000 square miles), and Georgina Poison Country (25,000 square miles). The New Guinea unit was established in 1953 and has completed surveys of the Buna-Kokoda Area (2,500 square miles), and the Wanigela-Cape Vogel Area (1,600 square miles).

The main function of each unit is to classify and map the lands according to surface characteristics of importance in the determination of land-use potential. The second is to make the best possible assessment of each type of country mapped. The surveys provide a basis of facts necessary for the formulation of policies concerning land development or conservation.

(*a*) *Australian Mainland Survey Unit*.—(i) *Georgina Poison Area*.—The survey team carried out further field work in the Georgina Poison Area which lies to the west of Dajarra, western Queensland, and extends some 100 miles into the Northern Territory. The objective was to examine the environment (rock, land surface, soil, vegetation) in relation to the known occurrence of poisonous and safe gidgee (*Acacia georginae*) and to undertake the normal regional assessment and mapping. Officers of the Animal Industry Division of the Northern Territory Administration and of the Queensland Department of Agriculture and Stock co-operated with the survey team in this project.

It was found that there was no clear regional correlation between edaphic conditions and occurrence of poisonous gidgee. However, except for one known poison area near Ardmore, Queensland, all of the known and suspected poison country is associated with pre-Cambrian dolomites or younger rocks that are probably at least partly derived from pre-Cambrian dolomites, but there are also large areas of pre-Cambrian dolomites with gidgee that is not poisonous.

At the present time there does not seem to be any further scope for field ecological studies in relation to the problem. However, it is hoped that chemical work being undertaken by the Animal Industry Division of the Northern Territory Administration will further define the problem, and further ecological studies may be necessary at a later date.

(ii) *North Kimberley Area*.—Mapping from aerial photographs was extended westward from the King Edward-Drysdale Area to cover the whole of the North Kimberleys. The western portion is mostly very rugged sandstone country with small isolated areas of better pasture on volcanic rocks.

The cattle carrying capacities were estimated by comparison with similar developed country in the adjacent Ord-Victoria Area. The areas suitable for beef cattle development have a total carrying capacity of approximately 43,000 cattle.

The Department of Lands and Surveys, Western Australia, used the information and maps provided by this Section in conjunction with data provided by their own field teams to prepare proposed subdivisions into holdings.

(iii) *Historical Study of Development in the Northern Arid and Monsoonal Part of Australia.*—During the course of the regular regional surveys there has been very little opportunity to study the history of development of the areas surveyed, and its influence on the present state and kind of development. An understanding of the reasons for the present degree and forms of development is essential to a sound prediction of the future land use. In order to provide this information a three-year study of the northern arid and monsoonal part of Australia has been commenced. It involves extensive searches of both governmental and private records as well as field investigations and interviews with local residents. Field investigations are now under way in northern and western Queensland.

(*b*) *Papua-New Guinea Survey Unit.*—In 1955, preliminary botanical investigations were made in the Gogol-Upper Ramu Area and the normal survey of that area is being commenced in mid-1956. Preliminary botanical investigations are now being made in the area to be surveyed in 1957, the Eastern Highlands Area.

The co-ordination of data and preparation of reports for the Buna-Kokoda Area and the Wanigela-Cape Vogel Area are now virtually complete. However, the preparation of final maps is awaiting the completion of accurate base map compilation from aerial photographs by the Department of the Interior.

3. Agricultural Research in North Australia.

(Land Research and Regional Survey Section.)

(*a*) *Katherine Research Station.*—(i) *Crops.*—The past season has again been a favorable one, on the whole, for crop production. Yields of sorghum and peanuts appear to be well up to the good standards of at least 2,000 lb./acre obtained in previous years. Cotton yields, as judged by inspection, appear to be better than for some years and should approach 1,000 lb. seed cotton/acre.

It has been found that the yield of sorghum is greatly influenced by atmospheric conditions, during and shortly after the period of anthesis. A change from wet to dry conditions led to a marked drop in the number of grains produced per head, but not to any marked change in grain size, with a drop in yield of approximately one-third.

With peanuts it would appear that there is a sudden check to further nut production towards the end of the wet season. Growth of the plant continues, as does flowering and peg setting, for some considerable time after nut formation has ceased. The only climatic factor showing any correlation with the cessation of nut formation was a marked drop in the nightly minimum temperature towards the end of the wet season.

Cotton at Katherine presents a complex picture. It is now being realized that the dominance of vegetative over reproductive growth is associated with the heavier periods of rainfall in the middle or latter part of the wet season.

There is some evidence that growth rather than reproduction in legumes may be favoured during hot, wet weather. This has been especially noted with guar.

(ii) *Fertilizers.*—Continual residual response to both rock and superphosphate have been obtained with sorghum and with peanuts.

(iii) *Cultivation and Tillage Practices.*—A repetition of an earlier experiment (1952-53) on time and depth of ploughing on the same site has again given very marked responses in favour of deep dry ploughing against shallower or later ploughing.

(iv) *Soil Moisture Studies.*—These have concentrated on the effects of cropping history and of land preparation on moisture retention and depth of penetration. Deep, dry ploughing gave better retention and penetration than all other treatments. Sorghum appears to leave the land in a state favouring increased water retention and penetrability.

(v) *Sown Pastures.*—Nine grasses of promise were established in pure stands at varying spacings in the 1953-54 season, but in their second full season (1955-56) all stands showed very marked deterioration. This agrees with previous small-scale experience on grass plots.

(vi) *Native Pastures.*—Observations on native pastures have been combined with the determination of weights of stock fed on them throughout the year. Stock gain weight rapidily and improve markedly in condition at the start of the wet season for two or three months. This is followed by a stationary period lasting until May-June, after which there is a steady decline in weight until there is new growth with the onset of the next wet season.

(*b*) *Kimberley Research Station.*—(i) *Crops.—Sugar Cane:* This crop continues to show excellent promise, with ratoon yields being maintained at high level. The best yield during the year was from a plant crop of the variety S.J.4 which gave 7.4 tons of sugar per acre.

Rice: Dry season trials on *japonica* varieties were rendered ineffective by finch damage during ripening, but vegetative growth suggested that these varieties might do better in the dry season than in the wet. The wet season crops of a range of *indica* varieties have averaged 2,700 lb./paddy acre over 10 acres. The highest yielding variety so far reaped is a Burmese one which has given 4,000 lb./paddy acre on a small plot of 1¼ acres. A range of *indica-japonica* hybrids supplied by the International Rice Commission's Hybridization Scheme was grown in single-row plots, but none of these has shown any particular promise.

Safflower: A crop planted in July, 1955, gave poor yields. It is thought that this was caused by the lateness of planting resulting in the crop flowering during the hotter weather.

Other Crops: Wheat, oats, and barley planted in the clay soil at about the same time also gave very poor yields, in spite of promising early vegetative growth. The oat plants, in particular, developed a severe leaf chlorosis at the heading stage, which was thought on visual symptoms to be due to manganese deficiency. Analyses of leaf material did not substantiate this view, since the leaves had approximately five times as high a concentration of manganese as is normally regarded as a safe minimum level. The cause of the chlorosis is being investigated.

Cotton: An excellent crop of cotton has been grown, almost entirely free from insect damage, control resulting from the use of endrin at frequent intervals. The first pick on the crop ranged up to 1,000 lb. per acre.

(ii) *Fertilizers.*—A disorder characterized by leaf and shoot drying out has been noted on rice, especially the *indica* varieties. As this leads to a large proportion of dead tillers, it presumably affects yield. The disorder is accentuated by phosphatic fertilizers, and is believed from pot experiments to be due to a nutritional imbalance between iron and manganese, both of which are found in the green leaf in relatively high concentrations. This disorder appears to occur in certain other rice-growing areas in northern Australia.

(iii) *Irrigation.*—More accurate measurements of water used are now possible, but these indicate that earlier measurements were substantially correct. It is believed that the better yields of paddy obtained this season than heretofore may be associated with an enforced lower water usage (resulting from pumping difficulties), and that surface aeration of the soil at intervals may well have been beneficial.

(iv) *Pests and Diseases.*—There was no serious outbreak this year.

(v) *Pastures.*—The most productive and persistent pastures on the clay soil have been those in which the legume *Clitora ternatea* is dominant. Elephant grass, cultivated in rows on the lines of sugar cane, has given good yields of green fodder.

4. CLIMATOLOGY.

(Land Research and Regional Survey Section.)

The investigations on natural vegetation at Kimberley Research Station have been continued. The rainy season just concluded was characterized by frequent falls of rain, and during the major part of the season there was little evidence of water stress on the plants. As a result, a considerable bulk of vegetation accumulated on the experimental area, consisting mainly of *Chrysopogon pallidus, Aristida latifolia, Iseilema* spp., and *Brachyachne convergens.* The drying of samples of this material for estimates of dry matter production presented a problem with the inadequate equipment available. Attempts to estimate the dry weight of plants without destroying them were unsuccessful. In some species tiller counts were complicated by the branching habit of the plants, in others the tillers were so numerous and variable in size that good estimates could not be made. In addition dry-season growth frequently hid young shoots of new-season growth. Soil moisture determinations were carried out by gravimetric sampling and by gypsum blocks. The latter instruments were in general very unsatisfactory in these heavy, swelling clay soils, and the sampling programme finally involved weekly gravimetric sampling, using block data only in a qualitative way to indicate zones and trends of moisture extraction.

Also at Kimberley Research Station exploratory experiments with rice were conducted. In conjunction with the Research Station's main rice experiments, small evapotranspirometers were installed in rice bays as the rice was sown. Measurements of water levels inside the drums were made when microclimatic conditions inside and outside were considered uniform. The data obtained are being analysed in relation to estimates of evapotranspiration computed from meteorological data.

Following collaborative work with the Division of Meteorological Physics, assembly and testing of microclimatic equipment was conducted under field conditions in northern Australia. With the wet and dry bulb temperature elements under study it was found the influence of a protective nylon and " Perspex " " cage " around the elements had no measurable effect on the sensitivity of the readings. Under the tropical monsoon conditions of high temperature and evaporation, a limitation to the wet bulb element in the form of an inadequate water feed was encountered. It was possible to increase the water feed capacity to a satisfactory level without significantly affecting the sensitivity of the element. This collaborative work, leading to the development of sensitive measuring equipment for climatological research in arid areas, is being extended in the coming year.

Further collaborative work with the Division of Soils is planned, which will lead to the adoption of neutron scattering techniques for soil moisture measurements in future soil moisture investigations where this technique may have special application.

In the studies of plant-water relations conducted by the Unit, attention has been paid to the significance of leaf turgor as an indication of water deficits in plants. A calibration has been made of leaf turgor against diffusion pressure deficit (D.P.D.) for different types of tissues (in effect simulating the pF/water content curves so widely used to characterize soils). This indicated that a close relationship existed between these factors which was relatively constant for any one variety examined. Moreover, mesic types of tissue showed considerable dehydration at fairly low D.P.D.'s, whereas in sclerophytic types of tissue high D.P.D.'s were needed to dehydrate tissue to the same extent.

The absorption of water through the aerial parts of plants, as dew and water vapour, is a subject of considerable interest. Equipment recently developed by the Unit has demonstrated that water is absorbed by the aerial parts of short leaf pine (*Pinus echinata*) seedlings and is transferred through the plant to the flask in which the roots are contained, as long as there is a diffusion gradient favouring such transport. Absorption has been demonstrated from atmospheres of 100 per cent. relative humidity and also from unsaturated atmospheres. It is thought that this may have significance in nature, particularly in dry areas where gradients favouring absorption may occur.

5. ARID ZONE RESEARCH.

(Land Research and Regional Survey Section.)

At Alice Springs work has continued along similar lines to last year, viz., broad ecological survey work and plant identifications. Several hundred more species have been determined and some of the taxonomic difficulties of the *Acacia aneura* (mulga) group have been resolved by specialized work.

Soil moisture studies in the mulga community have shown that the top two to three inches of soil dry very rapidly at any time of the year. The soil reaches wilting point in a few days and may be air-dry in two to four weeks. It is thought that the failure of buffel grass seedlings to survive, even though germination occurs after rain, may be correlated with this rapid drying of the surface soil. Seedlings of native plants survive for a longer period.

An ecological survey of 48 square miles of virgin spinifex (*Triodia basedowi*) country was made at the request of the Animal Industry Division of the Northern Territory Administration, which plans to conduct a grazing trial on the area. In addition to surveying the area, permanent photo points were laid out on six radiating lines from the central watering point. It is planned to revisit the area from time to time for observations.

A preliminary survey of the Wiluna area was undertaken. It was recommended that a more thorough survey by the mainland survey team be conducted as soon as possible. This was planned for 1956, but was postponed owing to lack of aerial photographs. Following the survey more detailed research, particularly " range condition " studies, are planned.

XII. FISHERIES AND OCEANOGRAPHY.

1. GENERAL.

The aquatic resources of Australia, including whales, the more important commercial fish, crustacea, and shellfish, require study to ensure their economic use and, where necessary, their management to prevent depletion of stocks. Fundamental to this study is an examination of the environment to ascertain the variations in oceanographic and estuarine conditions which affect organic productivity and are to a large extent responsible for fluctuations in fish occurrences. Through its Division of Fisheries and Oceanography the Organization provides facilities for these studies.

Division of Fisheries and Oceanography.—In January, 1956, Dr. G. F. Humphrey, Senior Lecturer in Biochemistry at the University of Sydney, was appointed as Chief of the Division.

The Chief of the Division has been appointed as a member of the Standing Committee on Oceanography of the National Academy of Sciences. During the year four officers were appointed as consultants to the Advisory Committee on Marine Sciences of U.N.E.S.C.O. Mr. D. J. Rochford was invited to attend a meeting of this Advisory Committee which was held in Tokyo in 1955. He was subsequently appointed as a member of the Committee and will attend future meetings. He was also appointed as Australian delegate to the sixth Session of the Indo Pacific Fisheries Council in Tokyo. Another officer of the Division attended the Scientific Sub-committee of the International Whaling Commission in London. An officer attended the Annual Symposium of the Gulf and Caribbean Fisheries Institute at the University of Miami, Florida.

The Royal Australian Navy provided funds for research on marine fouling. The Marine Underwater Paints Committee appointed by the Navy held its eleventh meeting at Cronulla. Two overseas visitors, Dr. Lawrence, Chief Scientist of the Admiralty Chemical Laboratory at Portsmouth, and Mr. L. T. Carter, Chief of Naval Construction, Admiralty, were present.

" Marine and Freshwater Fishes of Ceylon " by Ian S. R. Munro was printed and distributed by the Department of External Affairs under the Colombo Plan to countries of South-East Asia.

The Division is indebted to the University of Sydney and the University of Western Australia for laboratory accommodation for certain officers; to the Commonwealth Fisheries Office and to all State Departments of Fisheries; to the Tasmanian Salmon and Freshwater Fisheries Commission; to the Australian Museum; and to other Divisions of the Organization for co-operation and assistance. The Australian Whaliing Commission and the four private whaling companies co-operated with the Division in providing accommodation and assistance.

Messrs. Huddart Parker and Burns Philp allowed masters of their vessels to New Zealand and New Guinea to collect sea-water samples. This help is appreciated.

2. OPERATIONS OF RESEARCH VESSELS.

(Division of Fisheries and Oceanography.)

(*a*) *F.R.V.* Derwent Hunter.—Cruise 17 was a deep drop-lining cruise off the Tasmanian coast. Cruise 18, parts 1, 2, 5, 6, and 8 were hydrology and plankton cruises between Hobart, Sydney, and Melbourne. Cruise 18, part 3, was a tuna long-lining cruise off the New South Wales coast, which gave encouraging results—these are discussed in the tuna section of this report. Cruise 18, part 7, from 16th November to 15th December, was an oceanographical cruise from Sydney to Lord Howe Island and then to Brisbane, thence to Noumea, and back to Sydney.

(*b*) *F.R.V.* Gahleru.—Three cruisers were completed in July and August; to tag *Pinctado maxima* on mainland ground, for growth rate measurements at Darnley, and to check spat sets in the vicinity of West Island.

3. FISHERIES BIOLOGY.

(Division of Fisheries and Oceanography.)

(*a*) *Whales.*—During the whaling season (June to October) of 1955, the whaling stations were visited by officers of the Division to collect data on reproduction, growth, and condition of the stocks of western and eastern Australian humpback whales.

The catch returns from Australian shore stations in the 1955 season were analysed and a report prepared for the Scientific Sub-committee of the International Whaling Commission. It was shown that on the Western Australian coast, following the reduction in the quota of humpback whales for the 1955 season (owing, according to previous evidence, to a decline in this stock), the catch returns for the last season showed a remarkable recovery. The mean length of the catch increased, the length frequency distribution improved, and the percentage of immature whales decreased. It was pointed out that this was due to more stringent selection of larger whales during the 1955 season, the rate of catching showing a corresponding fall. It is to be hoped that this reduced quota and more careful selection will halt any further decline in this stock of humpback whales.

On the eastern coast of Australia (and in the corresponding Antarctic Area V), the humpback stock appears to be still in a reasonably stable condition.

Whale marking was carried out in Western Australia from the Western Australian State Fisheries Department vessel " Lancelin ", when 70 whales were marked. Of these, one mark was recovered two days later at the Carnarvon station from a whale shot at a position 20 miles south of marking; a second mark was recovered from a humpback taken on board a Norwegian factory ship six months after marking in position 64°05′S., 114°32′E. This position is in the Antarctic area where humpback whales from the Western Australian coast are considered to gather during the summer feeding period. In east Australia 200 whales were marked during the 1955 season. Of these two were recovered at Whale Products Station at Tangalooma. One whale mark fired in the 1954 season off Moreton Island was recovered from a female humpback in the same area during the 1955 season.

(*b*) *Sea Fish.*—(i) *Barracouta* (Thrysites atun).—A study of the food and feeding of this species in Australian waters, mainly in the principal fishing areas which are off southern Victoria and eastern Tasmania, was completed. In those areas the principal food organisms are the planktonic euphausiid crustacean *Nyctiphanes australis* and the nektonic fish *Engraulis australis* (anchovy). The anchovy's habit of spending much of the summer and autumn in the inlets makes it unavailable at that period to the barracouta, which then depend mainly upon *Nyctiphanes* for their food supply. At other times of the year both species are consumed.

Observations on the feeding of barracouta upon *Nyctiphanes* indicate that only fairly high concentrations of the latter can be utilized efficiently, and plankton work shows that such concentrations are not uniformly distributed throughout the barracouta fishing area. A close positive relationship between availability of *Nyctiphanes* and that of barracouta could thus be expected in the summer and autumn months. There is a general positive relationship between availability (catch per boat month) of barracouta and the percentage of barracouta stomachs containing *Nyctiphanes,* at those seasons, from year to year over the period 1948-49 to 1953-54, in both the above-mentioned regions.

The study of changes in condition (weight-for-length: fatness) in barracouta has also been completed. There is considerable variation associated with region, year, and time of year; significant variation associated with gonad condition, and negligible variation associated with sex. Eastern Tasmanian barracouta are fatter than those of southern Victoria. Information on condition during the off-season (winter) is so conflicting that it seems probable that some barracouta maintain condition and others (stragglers) lose it. Southern Victoria barracouta were much fatter, season for season, in 1950-51 than in any other year, notwithstanding the low consumption of food in coastal waters as noted above. This makes it certain that they obtained food elsewhere.

(ii) *Australian Salmon* (Arripis trutta).—Field studies on the salmon of Western Australia, South Australia, western Victoria, and western Tasmania have been terminated, and the material and data collected are being analysed and prepared for publication. It has been concluded that the fish of these areas comprise a single homogeneous population. The adult fish of this population are confined to Western Australia where they spawn. The juveniles migrate eastwards and occur in South Australia, western Victoria, and western Tasmania. They remain in these areas until the approach of maturity when they migrate to Western Australia.

Salmon have been tagged in western Tasmania and in South Australia. As yet no salmon tagged in Tasmania has been recovered in Western Australia, but in 1955-56 a further 34 migrants from South Australia to Western Australia were recorded; 52 of the 4,000 fish tagged in South Australia in the 1952-54 period have now been recovered in Western Australia. From one tagging experiment conducted at Kangaroo Island, South Australia, in 1952 when 104 salmon were tagged and released, seven tags have been recovered in Western Australia.

(iii) *Trawl Fish.*—Market sampling of the main species of trawl fish has been continued. The number of steam trawlers operating from Sydney dropped from ten to six in 1954, and it has now fallen to five.

The study of the tiger flathead taken by the Danish seine fishery off Lakes Entrance has been continued. Length measurements of 20,000 have been taken and 100 fish each month have been examined for gonad stages and stomach contents. More than 3,500 flathead were tagged in this area, of which 37 have been recaptured. The days of freedom range from two to 114. Tags were returned fairly steadily until three and a half months after tagging; then returns ceased. This may indicate that flathead remain on the same ground for periods of up to three months.

(iv) *Demersal Fish of the Continental Slope.*—The deep-lining programme was concluded in January with the final quarterly cruise of the F.R.V. *Derwent Hunter* in eastern Tasmanian waters. Prior to this, results from fishing tests in this area had suggested a seasonal migration of the main species encountered, *Hyperoglyphe porosa* (deep sea trevally). A movement was indicated from the 350-300 fathom zone occupied in winter (June-August) to the 250-200 fathom zone in summer (December-February) at which latter season the fish spawn. However, during the winter cruise of this year these fish were taken in greatest abundance at the upper limit (250-180 fm.) of their bathymetric range, a condition observed previously only during the summer months. These fish have been taken in comparable numbers throughout the year between depths of 300-200 fathoms with the exception of the period March to May (autumn) when, for reasons unknown, their availability is considerably reduced.

Should a commercial fishery develop from this deep-lining survey, it will be a drop-lining fishery operating almost exclusively on the stocks of deep sea trevally. The catches of this species by this method were 50 per cent. in excess of those obtained from conventional long-lining.

(v) *Tuna.*—The Division's steel wire tuna long-line was modified to allow for a greater number of hooks per unit of line. This modification decreased the number of men required to operate the line and reduced the maintenance. It was found that the catch rate compared favorably with that of Japanese vessels operating in the Pacific. The catch included large fish of up to 200 lb. in weight. Fish of this size are not usually taken by commercial fishermen trolling on the east Australian coast.

(vi) *School Shark* (Galeorhinus australis) *and Gummy Shark* (Emissola antarctica).—The investigation of school shark has ceased except to record return tags. During the investigation 6,273 sharks were marked, of which 1,401 were adults. A total of 319 tags or 5 per cent. have been recovered. Eighty-six were adult (6 per cent. recovery). One recovery was made from a shark after nearly seven years of freedom. There have been 39 recoveries from South Australian waters. Of the sharks tagged in South Australian waters there have been twelve recoveries, of which two were taken near Portland in Victoria. A total of 562 gummy sharks were tagged. There have been only eighteen tags recovered and of these only four give data on growth rate.

(*c*) *Estuarine Fish*—(i) *Lake Macquarie Investigations.*—Tagging of larger fish ceased in January 1956 when 20,000 fish had been tagged in twenty months. Direct proof that certain species may migrate from the lake on attaining maturity has now been gained for seven species: sea mullet, luderick, leatherjacket, flattail mullet, tarwhine, tailor, and squire.

The food habits of the majority of species have been investigated for the first time. The limited quantity of certain food organisms probably accounts for the scarcity of certain ground fish.

Three bottom communities can be recognized. The general limits of these have been mapped. The first is a weed flat with generally sandy bottom to a depth of ten feet characterized by *Zostera* and its associated biota. The second is a fringing fauna which forms a zone on the slope between the weed zone and the almost flat bottom of the lake; the substrate is sandy or pebbly and is characterized by a sponge *Telilla* sp., a mussel *Trichomya hirsutus,* and an oyster *Ostrea angasi.* The third is a central silt zone which covers the major area of the lake floor, whose characteristic and only abundant organism is a polychaet, *Maldane* sp. Diatoms are absent from this silt zone. Stomach examinations so far have revealed only two species of fish, trumpeter whiting and squire, feeding upon *Maldane.* This means that for most species the major area of the lake provides no food.

A catastrophic killing of fish and invertebrate fauna in Cockle Creek following acid discharge revealed firstly that the fish population was very much greater than either local opinion or Divisional netting had indicated and secondly that the fish fauna repopulated such an area rapidly after the pH returned to a tolerable level.

(ii) *Mullet.*—A series of three papers on the yellow-eye mullet has been prepared for publication. These show—

(1) The yellow-eye stocks fluctuate considerably from year to year but there is no indication of any depletionary trend.

(2) The scales can be used to estimate age and growth, but are unusual in that the annuli are clearer in the posterior segment; females grow more rapidly than males. The species matures at the end of the third year, males at a mean size of 24 cm., females at 27 cm. L.C.F. (length to caudal fork).

(3) Western and eastern subspecies or races can be distinguished on the basis of scale counts and time of spawning. Growth ceases in mid-winter.

(iii) *Queensland Investigations.*—Analysis of observations in the lower freshwater zone of the Albert River indicates that only two species, the sea mullet *Mugil cephalus* and the silverside *Craterocephalus stercus muscarum,* are permanent members of the fish fauna, but eighteen other species occur seasonally or transiently.

(iv) *Western Australian Investigations.*—Studies on the size at first maturity and on the food preferences of commercial estuarine species have continued.

(v) *Barramundi* (Lates calcarifer).—The field study on this species has been completed and the results are in process of analysis. Growths up to 20 inches in the first year, to 27 inches in the second year, and to 33 inches in the third year are indicated by recaptured tagged fish, length frequency studies, and scale studies. The species is sexually mature at the end of the second year. There are two major spawning periods, one prior to and one after the wet season. Not all mature fish seem to spawn every year.

(*d*) *Freshwater Fish.*—(i) *Trout* (Salmo *spp.*)—*Investigations in Tasmania*—The preparation for publication of the first two reports on the results of this investigation has now been completed. The routine sampling of the spawning runs at Lake Leake, the Great Lake, and Plenty River has been continued in order to cover as great a period as possible in the reports on these areas. A remarkable feature, possibly related to the exceptionally wet season, has been the upstream migration of fish in the Plenty River in the summer, during which 250 fish passed through the trap.

Electrical fishing equipment has been used to study the fish population of streams to compare the population above and below the natural barriers formed by waterfalls, in rivers which have received no hatchery fish for several years. The results show that the population is self-supporting above the falls and is not dependent either on the upstream migration of the inhabitants of the low reaches, or on releases of hatchery-reared fish.

In order further to test the effectiveness of stocking with hatchery-reared fish some 10,000 marked fish were released in North Esk River in places where the population had been studied last year. When this river was fished again during the summer some marked fish were recovered.

(ii) *Fish Culture Investigations in Tasmania.*—In June, 1955, the trout remaining from the 4,140 released the previous year in the dam at Dairy Plains were recovered, and 237 fish were found. It is believed that this poor recovery is attributable to predation by ducks. Bottom fauna values indicate that food was not a limiting factor in the survival of the fish, and the growth of the fish was satisfactory.

(*e*) *Crustacea and Shellfish.*—(*a*) *Western Crayfish* (Panulirus longipes)—In December, 1954, 2,169 " white " crayfish were tagged and released off Garden Island, Western Australia. These were all under the legal size of carapace length 2.75 inches. During December, 1955, 86 of these tagged crayfish were recaptured, 60 of which were measured and showed a mean carapace length of 3.03 inches. Only two of those recaptured had the true " red " colouration. At Rottnest Island several " white " crayfish were held in craypots of standard design, and it was observed that after three weeks they became " pink " and within two months they were fully " red ".

Routine collections of ovaries were continued on the commercial grounds and the periods of reproductive activity can now be defined for most grounds. On the shallow reefs at Rottnest Island mating occurs in July, but no spawned females were caught until November. It was noted that these females had orange eggs on their pleopods, and by December the eggs were brown. In January the larvae were released from the egg capsules which remained on the abdomen of the female. These females moulted soon after, and again in June.

(ii) *Southern Crayfish* (Jasus lalandii).—Various crayfishing areas were examined so that a suitable site could be found for an extensive tagging programme. Cape Sorell was selected, and 115 crayfish were tagged and released.

(iii) *Prawns.*—The prawn surveys carried out in Exmouth Gulf, Western Australia, in co-operation with the Western Australian Department of Fisheries from P.V. *Lancelin* were completed by working throughout the summer of 1955-56. Commercial tests by *Lancelin* and the commercial fishing boat *Jon Jim* took 6,000 lb. of prawns in three weeks in October.

(iv) *Pearl Oysters* (Pinctada *spp.*).—During this year 500 specimens of *Pinctada maxima* were tagged on the mainland ground and 200 at Darnley. A preliminary analysis has been made of the data on growth rate secured from tagged shell. This indicated that growth rate was slightly less than that postulated from other data, but this is to be expected because the cleaning of the shell for tagging interferes with its growth.

Culture experiments have been continued using *P. maxima* and *P. margaritifera.* Nuclei were inserted in 70 specimens of *P. maxima.*

A survey of an area to the south of Carpentaria Light Vessel, Torres Strait, was completed in April in conjunction with the pearling lugger A.K. *Phynea.* This area contained the famous New Mainland patch which yielded 1,300 tons of shell in about six months in 1929 and which has not been fished since. Small areas of likely shell bottom were located, but very little pearl shell was found.

(*e*) *Scallops* (Notovola meridionalis).—The Tasmanian scallop catch was sampled each week during the twelve weeks' season. The meats of this season were heavier per 1,000 scallops than those of the previous season. A record catch of 511 tons was marketed.

(vi) *Oysters.—Sydney Rock Oyster* (Crassostrea commercialis)—Severe flooding along the central New South Wales coast killed many oysters during the autumn of 1956. For the second successive year no winter mortality occurred in 1955.

Pacific Oysters (Ostrea gigas).—The Pacific oysters transferred to Mallacoota Inlet in September, 1955, spawned in January, 1956. Some spat has been discovered, but this is still too small to determine whether it is that of the Pacific oyster or local rock oyster which is at the extreme of its range at this inlet. In Port Sorell mass spawning of the oysters was observed by the resident officer on 24th February. Two days later a severe flood occurred, and it may be presumed that many larvae were either killed by the fresh water or flushed out to sea. Nevertheless in early June several recent spat were found in the vicinity of the beds.

4. ICHTHYOLOGY.

(Division of Fisheries and Oceanography.)

(*a*) *Reference Catalogue and Collections of Australasian Fish.*—A supplementary catalogue and index dealing with generic names and characters has been prepared, and a start made on a general card index to recent ichthyological papers. A commencement has also been made on re-organization of existing fish collections in possession of the Division.

(*b*) *New Guinea Fish Fauna.*—Collections of fish from trawling experiments in the Gulf of Papua and collections from freshwater streams in the central highlands and upper Sepik River system have been submitted by the New Guinea Administration for identification. Many new species, several new genera, and one new family have been discovered.

(*c*) *Handbook of Australian Fishes.*—Work is in progress on the compilation of an illustrated handbook of Australian marine and freshwater fishes. This will appear in monthly instalments over a period of five or six years in the " Fisheries Newsletter ".

(*d*) *Fish Eggs and Larvae.*—Emphasis has been changed from description of preserved planktonic fish eggs and larvae to culture of eggs and larvae under aquarium conditions. To this end the aquarium facilities have been greatly expanded by the installation of banks of glass tanks, an improved non-metallic piping system, and the construction of special equipment for the rearing of larvae.

(*e*) *Planktonic Eggs and Larvae from Hong Kong.*—Preliminary identification has been carried out on a series of planktonic fish eggs and larvae submitted by the University of Hong Kong in connexion with its mullet investigations.

5. HYDROLOGY.

(Division of Fisheries and Oceanography.)

(*a*) *Oceanic Investigations*.—In 1955-56 F.R.V. *Derwent Hunter* completed several cruises devoted entirely to hydrological sampling as well as some on which combined fishing and hydrology programmes were carried out.

In August, 1955, a cruise of some four weeks in the south-west sector of the Tasman Sea yielded further valuable information about the distribution of winter water masses particularly in the central Tasman and the south-west Tasman.

Unfortunately, bad weather curtailed the full sampling programme in the region south of latitude 40° S. On this cruise the chlorinity-temperature depth recorder and the geoelectric kinetograph were operated for the first time. Both instruments operated successfully for the earlier part of the cruise, but faults due to leakage in the former and bad weather difficulties in operation of the latter curtailed their use in the later stages.

In November, 1955, *Derwent Hunter* carried out a Bass Strait sampling programme. This cruise confirmed the existence of the water masses detected in 1954, but also stressed the need for more extensive surveys to the west into South Australia and to the west coast of Tasmania in order that the origin and circulation of the north Bass Strait water mass might be elucidated.

In late November, *Derwent Hunter* commenced her most ambitious cruise to date. The cruise plan called for a series of stations from Sydney to Lord Howe Island and from Lord Howe Island to Brisbane. The cruise was then continued to Noumea.

In the waters west of Noumea very low chlorophyll values were obtained and seemed to be associated with a water mass of very low total phosphorus content.

Surface sampling from merchant ships has been continued. T.S.M.V. *Wanganella* has regularly collected samples on the Sydney to Auckland and the Sydney to Wellington runs, but frequent change of officers has caused difficulties in maintaining this excellent source of valuable information. M.V. *Tulagi* and M.V. *Malaita* commenced sampling in the western and eastern sides of the Coral Sea respectively in December, 1955, and the results to date from this sampling have given a much clearer picture of the passage of water masses into the Coral Sea.

(*b*) *Coastal Investigations*.—The dilution of New South Wales coastal waters by fresh waters reached a maximum (for C.S.I.R.O. records) in March, 1956, when diluted coastal waters down to a depth of about 20 m. were found from Evans Head to the Eden stations. Off the north coast of New South Wales the dilution in this month corresponded to about a 15 per cent. introduction of river water.

The chlorophyll figures for a complete season at the Port Hacking station display a seasonal range of about 2 mg. chlorophyll per m^3 which is about one-third to one-quarter that in the English Channel.

Winds in the Sydney-Lord Howe Island-Brisbane triangle have been examined in relation to mean sea-level changes and some correlation between pressure differences between Sydney and Lord Howe Island and Port Hacking mean sea-levels have been found. However, there is a lag in response between them which suggests that circulation changes as well as the direct effect of wind stress are involved.

In south-west Australia the coastal stations off Rottnest Island and Albany have been sampled at about monthly intervals. The seasonal cycle of hydrological conditions off Rottnest is determined by the northern movement of cold high-chlorinity waters in the late spring and summer and by the southern movement of warm low-chlorinity waters in the autumn and winter. In the period of this report, this seasonal cycle was followed for chlorinity and temperature. There does not, however, seem to be any consistent seasonal cycle of phosphates or nitrates, and the average concentration of these nutrients remains low.

(*c*) *Estuarine Investigations*.—(i) *Lake Macquarie*.—Routine monthly surveys were continued throughout the year. The system was affected by summer floods, but the pronounced fall in oxygen tension of the bottom waters observed in 1954 was absent this year, and there was little build-up of organic nutrients in the sub-surface water.

The information obtained from the portable salinity temperature meter developed by the Division of Electrotechnology indicates that there are generally two distinct layers in the vertical profile: a homogeneous surface layer of varying depth and a subsurface layer of increasing chlorinity. The instrument has proved highly satisfactory, giving readings of temperature to the nearest 0.05° C. and of chlorinities below 16°/oo to the nearest 0.1, and above 16°/oo to the nearest 0.01.

Frequent sampling during the period when a serious mortality of fish occurred in Cockle Creek indicated the presence of acid, but this toxic acidity did not intrude into the northern part of the lake. The effect of the original acid discharge was overcome when an alkaline effluent was discharged into the Creek.

(ii) *Port Hacking*.—The oxygen and phosphorus cycles of surface waters in the south-west arm were studied in the summer of 1956, and it was observed that the seasonal isolation of the bottom waters was even more pronounced than usual because of the development of a considerable chlorinity gradient by summer floods.

Sampling in the Swan River, Western Australia, was continued, but severe flooding in the river effected the typical winter stratification which has been observed in previous years.

6. PLANKTOLOGY.

(Division of Fisheries and Oceanography.)

Clarke-Bumpus plankton samplers were tried on the Bass Strait and Noumea cruises of the *Derwent Hunter* and proved satisfactory.

Dense subsurface layers detected by echosounder over most of eastern Bass Strait in April, 1955, appeared to consist of heteropods (*Firoloida desmaresti*). Such an immense occurrence of primary carnivores in the plankton of Bass Strait was previously unsuspected.

7. MICOBIOLOGY.

(Division of Fisheries and Oceanography.)

A study of the rate of multiplication of certain phytoplankton elements has indicated that the rate in Australian waters is more rapid than those recorded for the North Sea.

8. GEOBIOLOGY.

(Division of Fisheries and Oceanography.)

Investigations of the ecology of the sulphur cycle were continued. A paper was prepared on the electrochemical reactions in the sulphur cycle.

A visiting scientist, Miss Margaret Mackay, from the St. Andrews University, collaborated with the Research Fellow of the Division in a study on the role of *Enteromorpha* in sulphate reduction processes causing the release of soluble phosphates in the estuary. Work was also done on the importance of minimum metals on the growth of *Enteromorpha* and *Dunaliella*.

Specimens were collected in the geothermal regions of New Zealand. Examination of these indicated the importance of microorganisms in this environment.

A considerable number of measurements and analyses were carried out on the muds of estuaries. A study of sulphur compounds of these muds indicated the existence of sulphides or sulphydryls of iron which were unstable in the presence of moisture and oxygen.

A new method was applied to the study of sediments by comparison of sieve methods of analysis with that of density. The dried muds after being crushed and ground to a suitable particle size were allowed to fall down columns of liquids of different densities.

In collaboration with Dr. J. Silberman at Sydney University, a study was made of the pigments of the purple and green sulphur bacteria, and of the green flagellate *Dunaliella*. The pigments were separated by cellulose-packed columns and circular-paper chromatography.

The sulphur cycle was studied by means of isotope ratios with Mr. A. Rafter, Isotope Laboratories, D.S.I.R., New Zealand.

The first phase in an investigation to establish the extent to which heavy metal sulphides are concentrated by biological activity was carried out recently in New Caledonia in collaboration with Dr. R. G. Stanton, University of Sydney.

9. MARINE FOULING.

(Division of Fisheries and Oceanography.)

The marine fouling investigations of the Division on the systematics, distribution, and seasonal intensity of fouling organisms have been terminated, and attention is now concentrated on studies of the larvae of fouling organisms at the settling stage. The larvae of the bryozoan *Watersipora cucullata* (Busk), the barnacle *Balanus* (*Balanus*) *amphitrite* var. *cirratus* Darwin, and the hydroid *Tubularia australis* Stechow have been taken through to the settling stage in the laboratory. The tube worm *Galeolaria caespitosa* Lamarck has been reared almost to the settling stage.

Experiments were set up to determine the relative sensitivity of various larvae to the toxic effects of copper and mercury. Results indicated that *Watersipora* larvae were relatively more susceptible to mercury, but that at certain concentrations copper apparently accelerated metamorphosis to such an extent that it became abnormal and lethal.

XIII. FOOD.

1. GENERAL.

The preservation of food is an increasingly important link between primary industry and the consumer market. There is a growing awareness of the part which science and technology can play in reducing wastage, improving quality, and generally raising the efficiency of Australia's food processing industries. The complex constitution of foodstuffs of all kinds, especially meat, dairy products, and fruits, calls for fundamental studies based on physics, chemistry, botany, and bacteriology to ensure the elimination of processing and storage conditions which tend to their deterioration. As a major food producing country situated far from the main food importing nations, and with its own population centres separated by long distances, Australia has a special interest in the preservation of foodstuffs during transport.

The Organization's work on food is undertaken chiefly within the Division of Food Preservation and Transport with its main laboratories at Homebush, New South Wales, and branch laboratories at Brisbane, Queensland (meat); West Gosford, New South Wales (citrus fruits); Eden, New South Wales (fish); Hobart, Tasmania (fish, apples, and berry fruits); and at the Botany and Biochemistry Departments, University of Sydney (plant physiology and physical chemistry). The work of the Division is described in Sections 2-11 of this Chapter. Work on the manufacture of dairy products is carried out by the Dairy Research Section at Highett, Victoria (*see* Section 13 of this Chapter). Co-operative investigations on wines are carried out in the Waite Agricultural Research Institute (*see* Section 12 of this Chapter).

Work on dried vine fruits is in progress at the Commonwealth Research Station (Murray Irrigation Areas), Merebin, Victoria (*see* Section 14 of this Chapter).

Division of Food Preservation and Transport.—The recent outbreak of Queensland fruit fly infestation in several areas producing citrus fruits is a serious threat to the substantial export trade in these fruits. The Division has been studying the effects on the fruit from three major districts of recommended post-harvest treatments for the killing of larvae and eggs in the fruit. This work is nearing completion. Together with entomological investigations and tests of sterilization techniques carried out by other bodies, the storage studies are directed by a joint technical committee of the Standing Committee on Agriculture. Additional facilities for entomological work have recently been erected at the Citrus Wastage Research Laboratory, Gosford, New South Wales.

The expanding work of the joint Plant Physiology Unit of the Division and the Botany Department, University of Sydney, has hitherto been seriously hampered by shortage of laboratory space. Considerable additions within the Botany Department have recently been completed, and will not only give the present research workers better facilities but will allow a small increase in the number of research students receiving training in the Unit.

The first Divisional conference on food chemistry was held at Homebush in March. Mr. E. W. Hicks, a senior principal research officer, attended the International Congress of Refrigeration held in Paris in August, 1955.

Greater efforts recently made to increase the number and scope of contributions from industry have resulted in an encouraging response from a wider range of interested organizations.

2. PHYSICS.

(Division of Food Preservation and Transport.)

(*a*) *Rail Transport.*—The performance of an ice-cooled refrigerator car equipped with fans in order to make it capable of cooling a load of warm fruit during the journey has been studied in collaboration with the Queensland Department of Agriculture and Stock.

(*b*) *Canning Processes.*—The heat transfer coefficient between the steam in a retort and liquid inside a can is not constant but is a function of the temperature difference and the thermal properties of the liquid. This leads to deviations of the heating curves from the simple form which is commonly assumed. These deviations are not usually of great importance in the practical evaluation of processes, but some calculations and measurements have been carried out to obtain more complete information on the form of the heating curves and the importance of various factors which affect it.

Many canned products consist of roughly spherical solids in brine or syrup. Theoretical analyses of the heating of such systems have been made in order to assist in the interpretation of experimental heating curves which are usually derived from measurements of temperatures in the liquid.

(*c*) *Evaporation in Cold Storage.*—The work referred to in previous reports has continued. Most of the work this year has been on the evaporation properties of fruits.

The variation in evaporation properties of Granny Smith apples grown in different districts was studied last season and is being studied again this season. Although there are some variations from season to season, the main trends seem consistent.

(*d*) *Water Relations.*—The study of water relations of foodstuffs and related biological materials is being continued. Further data on the vapour pressure isotherms of proteins have been collected and compared with published data. The apparatus has been modified and further consideration is being given to the most suitable techniques for obtaining data.

(*e*) *Colour Measurement.*—Attempts are being made to develop methods of measuring colour which will be suitable for routine applications. Fundamental data are obtained by measuring spectral reflectance curves. Several electrometer circuits have been tried with the photoelectric tricolorimeter and so far the type using a "chopper" and amplifier has given the best results.

(*f*) *Freezing Point of Whole Fruit.*—An attempt has been made to measure the freezing point of whole fruit and to find what relationship this bears to the freezing point of the expressed juice. Although the latter can be measured easily and accurately the usual techniques could not be applied to the whole fruit without considerable modification.

3. FOOD CHEMISTRY.

(Division of Food Preservation and Transport.)

(*a*) *Volatile Products of Apples.*—The volatile organic substances produced by fresh apples are being studied on account of their probable relation to storage behaviour, particularly to the disorder superficial scald. Tests for olefines failed to reveal any besides ethylene. The causal agent has not yet been identified but diphenylamine and other substances were found to control scald. These recent observations have suggested new lines of attack, which are being followed in the present season.

(*b*) *Natural Coating of Apples.*—The natural coating is the main barrier to gaseous diffusion, and probably controls the internal atmosphere and loss of water. A paper on the saturated acids of the cuticle oil has been accepted for publication. Work on the unsaturated acids, including the development of satisfactory derivatives, is continuing. The products of alkali degradation of cutin are being studied.

(*c*) *Determination of Ethylene Dibromide in Fruit.*—Work on the determination of ethylene dibromide (used for destroying fruit fly) in fumigated fruit was completed and a paper prepared for publication.

(*d*) *Anaerobic Decomposition of Ascorbic Acid.*—Work on the anaerobic decomposition of ascorbic acid (vitamin C.), which is responsible for its loss from stored canned foods, was recently resumed with the object of identifying the substances formed.

(*e*) *Water-soluble Constituents of Fruit.*—These studies are providing essential basic data for the investigation of chemical reactions occurring in the deterioration of processed foodstuffs. The results and techniques are also a contribution in the general field of plant chemistry. The sugars and polyols of the apricot fruit have been separated by chromatography using successively charcoal and cellulose columns and paper sheets. Sucrose, glucose, fructose, xylose, sorbitol, and *meso*inositol have been characterized by the preparation of crystalline derivatives. Some further work has been done on the identification of the free amino acids in apricots and peaches.

(*f*) *Chemistry of Non-enzymic Browning.*—Deterioration due to non-enzymic browning is mainly encountered in concentrated or dehydrated foods, but it can occur at normal water contents if certain types of reactive compounds are present. Freeze-dried fruit purées have been used as the natural system for investigating the primary reactions leading to browning. The cationic and anionic constituents of browned and unbrowned purées were separated by displacement chromatography. Among the reaction products found in the browned purée were 1-(*N*-amino acid)-1-deoxy-fructose, formed from amino acids and glucose, and esters formed from malic and citric acids and sucrose or glucose.

(*g*) *Protein Chemistry*—(i) *Urea and Heat Denaturation of Proteins.*—The phenomenon of denaturation of proteins by heat and organic solutes and solvents is well known to the food technologist. However, its exact nature is not understood. A comparative study is being made in this laboratory of the denaturation of proteins by heat and urea.

(ii) *Protein and Amino Acid Metal Complexes.*—A study has been made of the nature of the binding of copper and other metals to bovine serum albumin and certain amino acids. Attention is at present being focused on the combination of silver and mercury with proteins in the hope of devising suitable methods for kinetic studies on the liberation of -SH groups during protein denaturation.

(iii) *The Chemistry of Casein.*—Casein was one of the first proteins to be obtained in a relatively pure form. Despite this, much of the chemistry of casein is obscure; for example, there is little agreement among investigators about the molecular size of α– and of β–casein. Some clarification of this problem has come as a result of recent work in this laboratory,

(iv) *The Effects of Freezing on Proteins.*—Although changes in the physical and biological properties of high-protein foods like meat and fish have been observed frequently on freezing and thawing, little work has been done to define and characterize these changes. Few attempts have been made to separate and study individual effects of freezing by using well-defined protein systems and controlled freezing conditions. Preliminary studies of this nature in this laboratory have shown no change in the viscosity and optical rotation of ovalbumin and α–casein on freezing and thawing. Loss of soluble protein in skim milk is apparently connected with changes in the casein micelle rather than changes at a molecular level.

(v) *Kjeldahl Determination of Total Nitrogen.*—Work on the effects of temperature, catalyst, and oxidizing agent on the Kjeldahl determination of nitrogen has been extended to the microgram region.

(*h*) *Infra-red Spectroscopy.*—During the three past years the infra-red spectroscopic work has largely been directed towards a study of limonin, the bitter principle of Navel oranges. The whole question of the emphasis of the infra-red work in future is at present being considered.

(*i*) *Polarography.*—Some years ago it was realized that if the potentialities of polarography in the Division's analytical and physico-chemical problems were to be fully realized, accurate methods for the measurement of the characteristics of polarographic waves would have to be developed. A study of this type has been recently concluded.

4. MICROBIOLOGY.

(Division of Food Preservation and Transport.)

(*a*) *Water Relations of Microorganisms.*—An experimental study of the water requirements for growth has been almost completed for several strains of *Clostridium botulinum.* The lowest water activity permitting growth was close to 0.95, the lower limit being slightly lower for vegetative cells than for germination of spores. The water requirements for growth of *Pseudomonas fluorescens* have been found to be similar to 0, 10, and 30° C. A species of *Vibrio* has been found to require a comparatively narrow range of water activity for growth, the optimum zone being very sharply defined.

(*b*) *Bacterial Spores.*—The great diversity in the heat resistance of the spores of different species of bacteria has been recognized for many years, but is so far unexplained. Some recent experiments have shown that spores which have a low resistance to heating in dilute aqueous solutions and most foods have their resistance greatly exalted when they are heated at low water activity. For very heat-resistant spores the increase in resistance achieved by controlled drying was much smaller. The differences in heat resistance which are manifest in dilute solutions tend to disappear when the spores are heated under relatively dry conditions. These observations support the hypothesis that heat resistance in bacterial spores is associated with the maintenance of relatively dry conditions within the intact spore. The hypothesis suggests, for the first time, possible explanations for the great variations in resistance between the spores of various species of bacteria, and, if confirmed, may provide a rational basis for attempts to reduce the resistance of those spores which at present require inconveniently severe canning processes for their destruction.

(*c*) *Freeze Drying.*—Studies of the factors affecting death of microorganisms in dried storage have been continued and a large number of storage experiments commenced in the previous year have been completed. Many additional experiments are still in progress. Protection by a range of non-reducing sugars, amino acids, and some carbonyl reagents has been confirmed with a number of organisms. The kind co-operation of workers in two other laboratories has made it possible to show that some animal viruses are also protected by amino acids. Although the theory that death in the dry state is due to reaction between carbonyl compounds and amino groups on cellular proteins has received further support, direct chemical proof is not available. Applications for patent rights to certain improved processes for dried storage of microorganisms have been filed in several countries.

The construction of new equipment for study of the drying process under controlled physical conditions was completed. Performance of this equipment was considerably short of expectations, and some change of design will be necessary.

The mortality which dried microorganisms may undergo during rehydration has not previously been studied and, in general, has not even been recognized. This aspect of the problem has been studied intensively during the last twelve months and it is now clear that for some organisms the conditions of rehydration are of decisive importance. On the other hand, most organisms are apparently unaffected by wide variations in the conditions of rehydration. While the experiments have revealed some of the ways in which mortality during rehydration may be controlled, there is as yet no explanation available for the observed findings, or for the great differences in the susceptibility of various organisms.

5. MEAT.

(Division of Food Preservation and Transport.)

(*a*) *Co-operative Investigations.*—Co-operation with the British Department of Scientific and Industrial Research has continued in the investigations of various pre- and post-slaughter conditions on the quality of frozen beef. The present work, in extension of previous work, is concerned with detailed effects of relaxing doses of magnesium sulphate on beef with both rapid and normal slow freezing. The influence of pyrophosphate both specifically and as a means of producing hypocalcaemia has been studied. In these studies the previous criteria have been used together with an extension of the range of muscles studied, and detailed study has been made of the content of amino acids and proteins in the drip by using chromatographic and ultracentrifuge techniques. Through the use of insulin and combined fasting and exercise, the range of ultimate pH values available for study has been extended, and considerably more information is available for the range near pH 6.5. The use of tuberculin to produce shock, and neopyrithiamin with exercise and antibiotic treatment to reduce availability of glycogen, have been effective in producing high ultimate pH values.

(*b*) *Biochemistry.*—In extension of investigations on comparative biochemistry of post-mortem changes, further data have been obtained on whale muscle. Attention has been given to oxidation-reduction potentials and tissue gases. Analogous data have been obtained on beef muscle.

(*c*) *Bacteriology.*—Studies on the relation between time of development of rigor mortis and rate of development of micro-organisms on ox muscle have been extended to cow muscles. The relation in cow muscle would appear to be quantitatively less evident.

The effects of temperature and nutritional environment on a selected organism capable of causing spoilage in beef at low temperatures are being studied. Qualitatively, it has been found that the metabolism on a glucose medium is similar to that of some high temperature organisms of the same genus. The quantitative aspects of the influence of temperature are now being investigated.

(*d*) *Freezer Burn.*—Extension of earlier studies has indicated that in the absence of weight losses increasing freezing time contributes to reduction of freezer burn. Fat content has been shown to influence the results. Histological studies have confirmed the presence of air spaces left by the evaporation of ice crystals and have demonstrated the advance of the layer of air spaces with increasing severity of burn.

Absorption of small amounts of glycerine or hexoses in the surface of liver slices has been effective in reducing freezer burn even under very drastic conditions.

(*e*) *Ozone Studies.*—Conditions have been developed in which reproducible ozone concentrations in the environment and reproducible bacterial load on meat slices can be obtained. Studies on the influence of low constant levels of ozone on organisms are in progress.

6. FISH.

(Division of Food Preservation and Transport.)

(*a*) *Fundamental Investigations.*—Work has begun on some aspects of denaturation by freezing and by heating of muscle proteins in different fish species.

Further studies have been carried out on melanins obtained from prawn tissues.

(*b*) *Applied Investigations.*—The antioxidant properties of ascorbic acid used as a dip applied to fish fillets from two different species have been studied by means of tasting tests on frozen stored material.

" Fish sticks " prepared from scallops and from edible shark flesh have been tested for their storage behaviour during chilled and frozen storage.

Oil analyses of Tasmanian barracouta have been continued for a further season.

Work on the uptake of salt by the tail meat of whole crayfish during cooking in salt solutions of various strengths has been completed and a paper has been published.

Processing studies have been carried out on the canning of tuna and Pacific oysters.

7. EGG INVESTIGATIONS.

(Division of Food Preservation and Transport.)

Changes during Storage.—Certain disturbances, which include the development of a pink colour in the white, in cold-stored eggs have been traced to the ingestion by the fowls of plants from the family Malvaceae. These changes are similar to those taking place over a longer period in normal cold-stored eggs.

The active agent isolated from these plants is a C_{18} fatty acid. From the evidence supplied by selective hydrogenation and also from the infra-red absorption spectra of the acid and its partial hydrogenation product, the structure is at present partially defined as a fatty acid containing a propene ring.

8. FRESH FRUIT AND VEGETABLE STORAGE AND TRANSPORT.

(Division of Food Preservation and Transport.)

(*a*) *General.*—Co-operative research programmes were continued in collaboration with the University of Sydney at the Plant Physiology Unit, with the New South Wales Department of Agriculture, both at Homebush and at the Citrus Wastage Research Laboratory, Gosford, and with the University of Melbourne. The subjects investigated ave ranged from basic problems concerned with the ackground knowledge of fruit growth and metabolism o applied problems of improving storage quality and ecreasing wastage.

(*b*) *Plant Physiology and Biochemistry.*—Work in ollaboration with the universities is designed principally o study the physiological organization of the cell, the iochemical pathways, and the mechanisms controlling the ital processes. Investigation of the fine structure of the lant cell was continued in collaboration with the Division f Industrial Chemistry. Electron microscopic examination of the chloroplasts produced information concerning he development of their internal structure under normal onditions and the influence of light on such development. he effect of nutrient deficiencies on chloroplast structure was also examined.

Owing to the absence overseas of the officer concerned, he investigations into the nature of plant cell surfaces ave been suspended.

The study of effects of inorganic cations and anions on eetroot mitochondria was extended to the oxidation of educed diphosphopyridine nucleotide. Experiments were ontinued on the seasonal variations of the respiratory haracteristics of beetroot mitochondria.

Studies on the development of peas were extended and ossible mechanisms for the control of starch synthesis were considered. As starch is a major factor in determining the quality of peas, this work may have an mportant bearing on our knowledge of maturation processes in general. Methods for the analysis of individual ugars in peas were developed and the changes in sugars luring the growth of the pea were followed.

Measurements were again made of the concentration of cid-soluble organic and inorganic phosphate in maturing ea seeds with results similar to those obtained last year.

In collaboration with the Canning Section pea samples rom commercial crops were taken in Tasmania and the nalysis of these may lead to an understanding of the hanges in maturity as measured by the maturometer. The change in water content of the pea seed appears to be closely related to maturity.

Work on the synthesis of sucrose by plant enzymes was ontinued. The enzymes from peas involved in the tilization of sugars were further studied. The existence of an effect, analogous to the Pasteur effect, in cell-free xtracts from peas was confirmed and the mode of action of oxygen investigated.

Phosphate carriers play a major role in the control of espiration. Methods have been developed for the determination of adenosine diphosphate (ADP) and adenosine riphosphate (ATP) in plant tissue, and work has continued on their control of the "Pasteur effect" in pea seeds. t has been suggested that the rate of respiration of fruit may be a function of the ratio ADP/ATP and that a ise in this ratio may underlie the climacteric rise in espiration. Much is known about the chemical changes n ripening apples, but it has proved difficult to estimate ccurately the ADP/ATP ratio in this fruit and more uitable material is being sought for this work.

The study of the physiology of the development of orange fruits on the tree was continued with Valencia oranges.

(*c*) *Applied Research.*—(i) *Gas Storage of Apples.*—The study of the effects of varying levels of carbon dioxide and oxygen has been continued, particularly in relation to the development of superficial scald. Carbon dioxide influences mainly the retention of crispness, acidity, and flavour while oxygen is mainly concerned with colour changes. Scald is increased by carbon dioxide and is greatly reduced at low oxygen levels. The best atmospheric conditions for the gas storage of the important variety Granny Smith appear to be 5 per cent. carbon dioxide and 2 per cent. oxygen.

(ii) *Scald Control on Apples.*—Storage in an atmosphere containing the minimum content of oxygen will reduce the incidence of scald and preliminary tests indicated that diphenylamine, as was found in America, may be an effective inhibitor of this serious storage disorder.

(iii) *Apples—General.*—A survey of the temperature of carriage in three ships carrying apples from Tasmania to Sydney showed no unduly high temperatures at discharge. An examination of the commercial fumigation of Tasmanian apples with methyl bromide, which was required to kill European red mite, showed that some varieties could be considerably damaged by the treatment and that the injury was very similar to the carbon dioxide injury "brown heart".

(iv) *Pears.*—A further examination was carried out of the factors responsible for excessive mould wastage in fruit from a large packing house, and work is proceeding on the relation of spore loads and fungicidal treatments to wastage.

(v) *Control of Wastage in Citrus Fruits.*—Further work has been done on the time of application of the sodium orthophenyl phenate dip developed to control mould in oranges. In the winter months the maximum delay between picking and treatment for effective control is four days while in the warmer summer months the fruit should be dipped within 36 hours from picking. The elimination of the water rinse following the phenate dip, which is at present necessary to prevent "rind-burn" on susceptible fruit, would be a practical advantage. To this end work on the addition of various emulsifiers to the dip is continuing. The lemon storage investigations, which have shown how winter lemons can be stored successfully until the early summer months, have been concluded. The use of fruit wraps impregnated with sodium orthophenyl phenate has been found to give excellent control of mould attack, and endeavours are being made to eliminate the "rind-burn" which may follow their use, particularly in cold storage.

(vi) *Queensland Fruit Fly.*—Both low temperature holding and fumigation with ethylene dibromide are well recognized methods of sterilization of fruits infested with fruit fly. In conjunction with the New South Wales Department of Agriculture an extensive survey was carried out with oranges from the main producing centres to define the conditions under which these treatments could be safely applied without injury to the fruit. Extensive data were obtained on the adequacy of shorter periods of low temperature storage for killing the fly. As a result of this work successful representations were made to the New Zealand quarantine authorities to reduce the required period of low temperature treatment. This reduction will enable a wider range of oranges to be exported to that country.

(vii) *Packaging.*—The use of sealed polythene case liners shows promise of being an easy means of increasing the cool storage life of apples and pears by effecting "in-case gas storage", and this aspect of fruit storage is being further developed.

The costs of marketing fresh fruit are now so high as to threaten the prosperity of the industry. Elimination of the use of the standard wooden box as a container and adoption of some method of bulk handling would effect great savings. Possible alternative methods of packaging oranges for transport and marketing are being considered in co-operation with the citrus industry.

9. Canning and Fruit Products.

(Division of Food Preservation and Transport.)

(*a*) *Vegetable Canning.*—The economic importance of green peas in the food processing industry in Australia provides justification for the sustained investigation of quality factors which was begun in 1944. During this period emphasis has been given to the maturity of the peas at the time of harvest, since the quality of the raw material is the limiting factor in the acceptability of the final product. It has been found possible to state clearly the limits for desirable harvest maturity, and processors have been given information which will permit them to harvest at the point desired. This maturity work was carried out initially in Tasmania, but subsequent work in Victoria, New South Wales, and America has shown that green peas conform in their maturity behaviour to a general pattern, which required some modification with respect to climate.

The variety of pea is probably a primary factor in determining quality, and work has commenced on varietal evaluation using the knowledge gained in maturity studies to ensure comparison at comparable maturities. This work is in its initial stages.

The operation of the pea viner, which recovers the peas mechanically from the vines, has been found to exert an appreciable influence on the texture of peas. A series of small-scale investigations of the effect of viner speed have been carried out for several seasons. Conclusions from this work were tested in Tasmania in January, 1956, under full-scale commercial operation and they were found to be valid. It is now possible to recommend a single viner speed for maximum pea recovery and for minimum damage, when peas are harvested at the correct stage of maturity.

When peas are harvested at the most desirable stage of maturity they contain small quantities of second-grade overmature and undermature material. The separation of first- and second-grade peas by mechanical means presents a problem of some magnitude. The usual procedure for this purpose is gravity separation in salt solution in which the youngest peas tend to float and the most mature sink rapidly to the bottom. Separation in salt solution is complicated by factors other than the specific gravity of the peas, and the process is consequently being investigated with a view to improvement in efficiency.

The initial series of investigations of maturity changes in green beans during crop development were completed. Canning quality in Landreth Stringless variety remained satisfactory until the beans reached 7 per cent. alcohol insoluble solids content, at which stage the seed contributed about 16 per cent. to the total weight.

Investigations of techniques for comparative evaluation of canning and of pulping varieties of tomatoes are being continued. The laboratory examination of canned material from the 1955 trials at Cowra and Richmond, New South Wales, is nearing completion. The 1956 trial at Richmond was ruined by adverse weather.

(*b*) *Fruit Canning*.—During several seasons it has been shown that trees of freestone peaches may be stripped of fruit in a relatively immature condition, which after ripening may be canned to give a product of satisfactory quality. Some inconsistencies in results have been attributed to the selection of the picking date by personal judgment, and the need for specific definition of maturity by mechanical or chemical means became apparent. A detailed study of fruit maturation to include growth rate, pit hardening, and changes in chemical composition has been started at Bathurst, New South Wales, with the co-operation of officers of New South Wales Department of Agriculture. Growth increment curves from fruit from eight trees suggest that a well-defined incremental peak subsequent to pit hardening may provide a reference point adequate for maturity studies. The work will be continued.

A procedure has been developed for canning dessert berry fruit in syrup containing added pectin. The process improves the quality of the pack by retarding changes which normally occur on prolonged storage.

A problem of tainting in canned fruits was brought to the notice of the Division during the year and appeared at first to be of widespread significance since it was reported not only in Australia but also in Kenya, Malaya, and South Africa. After extensive investigations it now appears most likely that the tainting was caused by accidental contamination with lubricating oils from canning or canmaking machinery. With the co-operation of the Tatura Research Station of the Victorian Department of Agriculture, a trial was made of a number of organic pesticides applied to pears, but no evidence of tainting in the canned products was detected.

Concentrated orange juice is being studied as a pasteurized product. Heat penetration measurements in rotating cans have defined the conditions for stability against microbial spoilage, and the flavour stability during storage of the pasteurized product is being examined.

(*c*) *Chemistry of Processed Foods*.—Chemical studies of limonin, $C_{26}H_{30}O_8$, the bitter principle of oranges, have been concentrated on attempts to locate the various functional groups around the reduced naphthalene nucleus, and in particular to establish the group relationships which are responsible for the unusual reactions of limonin. It is now possible to propose partial structures for several degradation products and it is hoped that a study of an interesting series of C_{21} derivatives will further clarify the problem of the constitution of limonin. In addition a derivative of limonin containing an asymmetric centre and a heavy marker atom is being sought, in order to permit a direct determination of the molecular structure and absolute configuration of limonin by X-ray crystallographic analysis.

The natural red pigments, known as anthocyanins, which are responsible for the characteristic colours of berry fruits, cherries, grapes, and beetroot, suffer deterioration during processing and storage, and they accelerate the corrosion of the tinplate containers. As the first stage of an investigation of the behaviour of anthocyanin pigments in canned foods, the pigments of blackcurrants have been isolated and purified. The two main constituents appear to be glycosides of cyanidin and delphinidin. An allied problem is the appearance of pink colours in colourless foods during heat processing. In this connexion a study of the occurrence of leucoanthocyanins in Packham pears has been commenced.

A study of the mechanism of destruction of chlorophyll during the processing of canned green vegetables has been commenced in an attempt to improve the colour factor in such products as canned green peas.

(*d*) *Container Investigations*.—Studies of the effect of different amounts of initial oxygen in the headspace of canned acidified beetroot on subsequent production of hydrogen gas during storage were continued. Gas production has been followed in two test packs of beetroot, and results confirm that high initial oxygen levels accelerate hydrogen production in store. Importance attaches to these results because of commercial losses in canned berries and acidified beetroot due to hydrogen swelling.

Further observations have been made on the performance of universal can lacquers tested with a range of canned products. Results have led to the testing of modified formulations with sufficient improvement in performance to warrant an extension of their commercial use during the year.

The investigation of electrolytic differential tinplate in co-operation with the Commonwealth Canmakers' Association has been continued. Twelve test packs in 1 lb. electrolytic plate have been compared in performance with the same material in standard hot-dipped 1.25-lb. tinplate. Foods selected for the work included those which normally require lacquer protection for sulphur or acid resistance as well as some which are packed in unprotected cans. In most cases the performance of both types of plate are similar and satisfactory. With several products electrolytic tinplate was found to be inferior to that dipped, while in one outstanding test the reverse was found to be true. As yet there is no systematic cause apparent to account for these differences in behaviour.

Samples of heat-resistant plastic film capable of withstanding retort temperatures to which canned foods are normally subjected were tested with a number of low acid and high acid foods. Claims for heat resistance were confirmed, but the heat welded seams were found to provide a point of weakness, and further investigation into alternative methods of sealing is indicated. Such packs, when perfected, may prove of value both for military and civilian purposes.

10. Frozen Fruits and Vegetables.

(Division of Food Preservation and Transport.)

Investigations of the freezing of fruits and vegetables are conducted jointly by the New South Wales Department of Agriculture and the Division of Food Preservation and Transport.

(*a*) *Freestone Peaches*.—Experiments on the use of ascorbic acid for preventing discoloration in frozen peaches were completed during the year. The results were in agreement with those of the previous season in which it was found that the level of ascorbic acid should be at least 150 mg./lb. There appeared to be no further improvement in quality when the amount of ascorbic acid was increased beyond the 150 mg./lb. level. There were some differences between varieties in the effect of any particular amount of ascorbic acid, but the maximum protective effect was generally obtained at the above level. Rates of loss of ascorbic acid during the storage were determined.

(*b*) *Berry Fruits*.—Studies on the freezing of berry fruits were undertaken on a co-operative basis with the Organization's Tasmanian Regional Laboratory and the Tasmanian Department of Agriculture. Most of the past year's work was related to the storage life of the products at temperatures of 0 and 14° F. Samples of frozen raspberries at 14° F. showed a significantly greater deterioration in wholeness and shape when compared with those stored at 0° F. Significant changes in quality with increasing time of storage were observed at both temperatures for both raspberries and strawberries.

(*c*) *Peas*.—Experiments on the suitability of pea varieties for freezing have continued. Studies on the maturity of peas for freezing have been extended to a commercial plant. While this work is still at an early stage, it has already yielded results which have been of practical value to processors.

The deterioration of " vined " peas during handling and transport before processing has been a major project in the freezing research programme. Data from the work of several seasons give a fairly clear picture of the nature of the deterioration and the effect of factors such as time and temperature of holding on palatability, ascorbic acid, and sugar content.

(*d*) *Sweet Corn*.—A comprehensive experiment on the relationship between quality and maturity was undertaken during the year. While considerable amount of data on the value of different laboratory tests in assessing the maturity of frozen sweet corn was obtained, the results for the quality-maturity relationship were inconclusive. It is probable that the occurrence of prolonged wet weather during the harvesting period may have been responsible for some inconsistencies in the results. The work will be repeated next year.

(*e*) *Stringless Beans*.—Tests of recent introductions of stringless bean varieties were undertaken during the year.

(*f*) *Miscellaneous*.—A comparison of a photometric method of determining ascorbic acid in frozen peas with the standard titrimetric method was made. The values for the photometric method were slightly lower on the average than those for the titrimetric method. There appeared to be very little practical advantage in favour of the photometric method.

An experiment, in which four transparent plastic packaging materials were compared showed no differences in the quality of frozen peas stored in containers made from those materials.

The use of pectin in improving the appearance of frozen fruits was investigated in a small trial with bananas, papaws, and strawberries.

11. Dehydrated Foods.

(Division of Food Preservation and Transport.)

(*a*) *Vegetables*.—A study was made of the size-maturity relationships on a pea crop at Hawkesbury Agricultural College with a view to determining the optimum harvest time for dehydration. The maturometer readings were used for determining the levels of maturity on the tests. This initial trial suggests that peas for dehydration should be harvested at least one day before peas for canning in order to produce optimum quality.

An experiment was commenced to provide data on the rate of deterioration of dehydrated peas stored in cans containing different tensions of oxygen.

Various freezing and thawing treatments were applied to carrots before drying in an attempt to increase drying and reconstitution rates. Fast freezing followed by slow thawing resulted in a faster drying rate initially, but over the full drying times no significant differences occurred.

(*b*) *Fruit*.—Experiments on the factors affecting the uptake and retention of sulphur dioxide gas by cut fruits before dehydration have been continued. More exact data have been obtained on the weight-surface rates as this affects absorption. Means of improving retention look promising. Apricots, peaches, and peas were used as experimental material.

Propylene oxide has been effective in preventing mould development in prunes with moisture contents up to 33 per cent. which are packed in sealed " moisture-proof " bags. Work on the estimation of propylene oxide or its hydrolysis product, the glycol, is proceeding. Sorbic acid which has been used widely as a fungicide in food products overseas also looks promising for high-moisture prunes.

Some work was done to assist cherry growers in improved methods for brining cherries. Better efficiency and quality is needed to meet competition by imported fruit. The work was hindered by heavy losses in the field owing to wet weather.

(*c*) *Meat Dehydration*.—(i) *Dehydrated Mutton*.—Long-term storage experiments have been continued. The investigations, which were designed to measure the effects on storage life of residual oxygen in gas packs, have now been completed. The results should make it possible to fix safe levels for commercial gas packing.

The study of the effects of flavouring additives both on flavour and on shelf life has been continued.

Experiments have been designed to limit deterioration during storage by controlling the " browning reaction ". These include treating the meat with different quantities of sulphur dioxide and by lowering the moisture content of the meat in the can by the inclusion of a desiccant.

Close liaison with similar laboratories in the United Kingdom and New Zealand has been maintained. A joint experiment with the British laboratory has been carried out to compare effects of raw material (Merinos versus English breeds of sheep), methods of processing, and methods of tasting.

(ii) *Dehydrated Beef*.—Storage studies on dehydrated beef mince are being continued.

A joint experiment has been carried out with the New Zealand D.S.I.R. meat laboratory. Dehydrated beef chunks prepared from different grades of meat were dried under vacuum in New Zealand and storage studies on the material are now in progress in Australia.

12. WINE.

(Oenological Investigations, Waite Agricultural Research Institute.)

The investigations directed by the Committee on Oenological Research are carried out at the Waite Agricultural Research Institute and are concerned with technological problems of the wine industry and improving the quality of Australian wines.

(*a*) *Malo-lactic Fermentation.*—Further data have been collected which indicate that bacterial decomposition of malic acid is particularly common in dry red wines having pH values above about 3.6.

In more acid wines and particularly in white wines, however, this fermentation occurs very irregularly. Studies with pure cultures in the laboratory have indicated that strains of the bacteria differ in their tolerance to acidity and that acid tolerance is influenced by alcohol content and sugar content of the medium. The bacteria responsible for malolactic fermentation belong to the genus *Lactobacillus* and are capable of causing spoilage of wines under certain conditions.

(*b*) *Influence of Commercial Refrigeration on Wine Composition.*—The refrigeration of wine to precipitate excess potassium bitartrate is an important aspect of wine maturation in Australia, and refrigeration is also claimed to improve the quality of wine in other ways. An examination of wines before and after commercial refrigeration was undertaken to measure the changes in composition brought about by the treatment. Changes were observed in tartaric acid, potassium, red pigment, titratable acid, iron, copper, total nitrogen, and pH.

(*c*) *Lead Content of Australian Wines.*—The British Ministry of Food has recently introduced a legal limit for lead in wine of one part per million. A range of 55 Australian wines were analysed and all were found to contain less than this limit. The Ministry has intimated that they intend to reduce the limit and accordingly further work is in progress to find out the sources of lead in wine. Results to date indicate that most of the lead present arises from contamination with lead containing winery materials, such as brass equipment and rubber hoses, and the use of lead sprays in the vineyard. The lead content of washed grapes is uniformly low.

13. DAIRY PRODUCTS.

(Dairy Research Section.)

(*a*) *General.*—At the beginning of the year, the Dairy Research Section moved into modern, well-equipped laboratories at Highett, Victoria, and has already felt the benefit of the improved facilities.

The Officer-in-charge spent six weeks in India and South-East Asia. He visited India as a member of a team set up by the Food and Agriculture Organization to study the scope for providing assistance to city milk supply schemes, including the use of "toned" milk. On his way home, he also discussed reconstitution schemes with civic authorities in Singapore and Darwin.

Two officers represented the Section at the annual meeting of the American Dairy Science Association in June.

An officer of the Section is spending a year in the Dairy Science Department of the Pennsylvania State University. He is studying flavour defects associated with the irradiation of dairy products.

During the year, 12,000 freeze-dried cultures of cheese starter bacteria have been distributed to Australian cheese factories, through the various State Departments of Agriculture.

The Queensland Butter Board and other industrial dairy organizations have made use of the pilot-plant facilities of the Section in various developmental projects.

Close co-operation has been maintained with State Departments of Agriculture, dairy manufacturing companies, and dairy engineering firms. The assistance given by these organizations is gratefully acknowledged.

(*b*) *The Utilization of Skim Milk Solids.*—The modified milk protein product developed for use in cake-making is creating interest in the pastrycook trade. New baking formulae and mixing techniques have been developed to facilitate the use of this product.

The study of scientific aspects of the processes involved in the modification of milk protein has been continued. The detrimental effect of lactose on the development of maximum foaming capacity was further studied, and whipping tests, development of browning, and the increase in acid-ferricyanide reducing groups all showed the effect to be less when the protein and calcium hydroxide were reacted for some time before adding lactose to the system.

The viscosity changes occurring on the addition of calcium hydroxide were found to be almost identical in the case of skim milk concentrate and dialysed skim milk with the same protein-water ratio, which indicated that lactose plays no part in the reaction.

(*c*) *Vitamin Fortification.*—The project on the vitamin A fortification of skim milk powder is nearing completion. It has been found that vitamin A can be carried in a hydrogenated coconut oil vehicle, and should be homogenized into milk concentrate before drying. Tocopherols are the most suitable antioxidants. Tests have shown that a very high percentage of the vitamin in the fortified powder will survive for long periods at equatorial temperatures.

The influence of several variables has been studied. These variables include preheating treatment, "instantizing", and the use of variant forms of the vitamin.

(*d*) *Market Milk and Cream.*—Several years ago a survey revealed that light-induced "oxidized" off-flavours were prevalent in the Melbourne domestic milk supply. The protective effect of amber-glass bottles and waxed paper cartons has been studied. Both containers reduce the incidence of off-flavour due to sunlight. The beneficial effect of amber glass is offset by a pronounced temperature rise in the milk, due to the greater heat absorption of the glass. Waxed cartons, on the other hand, have an insulating effect, keeping the milk cooler.

The development of oxidized flavours in milk and other dairy products has been attributed to the oxidation of phospholipins. These compounds are present in low concentration, and their isolation has hitherto proved difficult. New chromatographic techniques are being applied to the isolation and identification of phospholipins as a first step towards a better understanding of their role in flavour deterioration.

The marketing of table cream would be made easier if its keeping quality could be extended, and experiments with this aim are being carried out using the antibiotic preservative substance nisin. (Nisin is a by-product of certain lactic bacteria; all tests so far have shown it to be entirely harmless when consumed.)

(*e*) *Microstructure of Dairy Products.*—Certain synthetic surfactants, when added to milk before drying, are known to increase the wettability of the milk powder. Microscopic studies have shown that the surfactants cause fat clumps and globules to disappear from the surface. Thus with no fat in the surface layer, the dry powder particles are more hydrophilic. Quantitative studies of the hydrophobization of fat globules on the surface of milk by the action of alcohols show pronounced differences in effect between various alcohols. Analogies could be drawn with the splitting effect of certain alcohols on biologically important lipoproteins.

A technique for staining bacteria in very thin sections of milking machine rubbers has been developed. The microscopic picture supports American observations on the retention of bacterial agglomerates by cracked and eroded rubber surfaces of milking machine parts.

(*f*) *Cheese Starters.*—A search for a new, more active thermoduric starter for use in the new short cheese process, yielded a fast acid producing strain of *Str. thermophilus*.

Antisera to lactic phage races have been prepared in rabbits. A method for determining the concentration of these antibodies has been selected.

The susceptibility of cheese starters to various inhibitory substances such as the antibiotics penicillin and nisin, and the naturally occurring lactenin, are being studied. Data obtained in these studies should be of practical value to cheese-makers.

(*g*) *Cheese Manufacture.*—Thermoduric starters have been found to contribute appreciably to acid production in the manufacture of Cheddar cheese by the new method, and it has been found possible to correct the defects due to high pH in cheese made by this method.

The development of the new method has led to the completion of preliminary work on mechanization. A "cheddaring" or curd-fusing machine has been designed and is under construction.

A search is being made for methods for the production of other varieties of cheese on the factory scale, without excessive use of labour.

Two procedures have so far been worked out. One process is for a cheese closely resembling the Edam variety, and the other is for a harder "Roman" type. Both procedures are extremely simple and amenable to mechanization. The cheeses have been produced so far only on the pilot scale.

(*h*) *Solids-not-fat Determination.*—In an effort to provide a suitable simple field test for the determination of solids-not-fat in milk, an extensive study of lactometry is being made. Data on the errors, limitations, and possibilities of the lactometer are being collected.

14. Dried Vine Fruits.

(Commonwealth Research Station, Merbein.)

Trials for the 1956 harvest on the commercial cold dipping oils for sultanas showed that all oils produced dips of similar stability and drying properties, and fruit of the same quality. Trials at Woorinen with the boiling sulphite dip indicated that a sulphite spray retarded the drying rate and produced sticky fruit of a lower grade. It was shown to be possible to use the cold dip in the Swan Hill district to dry sound fruit satisfactorily without green tinge and mould losses. Increasing the oil concentration of the sulphite dip retarded the drying rate.

The ease with which a cold dip ferments increases with increasing sugar content in the dip liquor. There is initially a gradual decrease in pH to about 9.3 after which there is a rapid decrease in pH accompanied by fermentation.

Further studies on the physico-chemical aspects of grape drying showed that the heat transfer from the air stream to the grape is a very important factor in the drying operation. This heat transfer is required to supply the heat of evaporation of water and to heat the fruit to equilibrium drying temperature. Indications are that drying rate is controlled by diffusion of water through the cuticle, being inversely proportional to the amount of cuticle that can be removed by extraction with a volatile organic solvent. During drying, the permeability decreases owing to an increase in the relative thickness of the cuticle caused by a contraction of the skin. Experiments at different temperatures suggest that the permeability increases approximately twofold for a 10° C. rise in temperature.

XIV. FOREST PRODUCTS.

1. General.

Australia is not a heavily forested country, although a wide range of eucalypts and other species of timber is available. Full and proper use of existing timber resources is therefore essential, and this can can only be achieved with the aid of fundamental data on the properties, potentialities, and correct methods of treatment of our timbers.

The Organization's Division of Forest Products, with its laboratory in Melbourne, was formed to carry out investigations on Australian forest products and to give direct assistance to all concerned in the utilization of forest resources. Its work is directed toward the more effective use of those resources, by reducing waste in forest, mill, and factory; by reducing losses from decay and insect attack; and by improving the quality of timber produced in the growing forest by the study of the relationship between silvicultural treatment and timber products. The work of the Division is reported in this chapter. Some work on timber pests is undertaken by the Division of Entomology (*see* Chapter IX.).

Division of Forest Products.—Although the level of operation of wood industries fell somewhat during the year, there was an increase in inquiries, which exceeded 10,000. Visitors to the Division were approximately 1,900, as for last year.

The outstanding feature of the year was the increased contribution towards the funds of the Division from outside sources. In addition to the contributions from the Pulp and Paper Industry which were continued, general contributions rose to over £3,000 from some 40 organizations and individuals, and substantial contributions for pole and plywood research were arranged.

Following discussions between the State Electricity Commission of Victoria, the Postmaster-General's Department, and this Division, a Committee was formed with representation from the Electricity Supply Association of Australia, representing all major supply authorities, the Postmaster-General's Department, the Victorian Forests Commission, and the Division of Forest Products. It was decided to proceed with the pole investigations, and a basis for contributions towards the cost of the work was arranged. Total receipts approximate £8,500 from 32 different authorities, and the value of material supplied in addition has brought total contributions over £10,000; a similar amount has been promised for the coming year. A pleasing feature of the arrangement is the large range of pole users interested so that rapid application of test results is assured.

This year it became necessary to decide whether to abandon work on plywood or to reorganize it. Following discussions with the Australian Plywood Board, agreement was reached whereby the Board will contribute £8,000 per year towards the cost of this work. Here again participation by the industry will facilitate application of the research results, and the Board has set up a small technical panel to keep in close touch with the Division. This example could well be followed by other wood industries.

The timber mechanics investigations at the Engineering School, University of Western Australia, have been continued.

The Chief of the Division, Mr. Stanley A. Clarke, visited Forest Products Laboratories in United States of America, Canada, England, Sweden, and Germany, while overseas in 1955. Mr. H. G. Higgins, of the Wood Chemistry Section, attended the Fourth International Congress of Pure and Applied Chemistry at Zurich in July, 1955, and the Third International Biochemical Congress in Brussels in August, 1955. Mr. W. E. Hillis, of the Wood and Fibre Structure Section, attended the symposium on "Vegetable and Synthetic Tannins" which was held at Cambridge in April, 1956.

The Fifteenth Pulp and Paper Co-operative Research Conference was held at the Division in January, 1956. The Eighth Australian Forest Products Research Conference was held in Melbourne in April, 1956, and attended by officers from the Australian and New Guinea Forest Services. During May, 1956, a symposium on "The Sorption of Water by Porous Materials" was held for officers from fifteen divisions of C.S.I.R.O

2. WOOD AND FIBRE STRUCTURE.

(Division of Forest Products.)

(*a*) *Identification and Identification Methods.*—Some 700 timber specimens were identified during the year for various organizations. In addition, more than 450 New Guinea wood specimens were identified on behalf of the Land Research and Regional Survey Section. A revised card has been prepared for use in the card sorting key based on macroscopic features. In the revision full consideration has been given to inclusion of additional features while at the same time taking care not to interfere greatly with the format of the existing card. The first work with the new card has been carried out with selected timbers from the New Guinea region.

(*b*) *Anatomical Investigations*—(i) *Wood.*—The structure of *Corynocarpus*, a genus confined to Australia and the south-west Pacific area, has been studied in some detail because of the great resemblance of its wood anatomy to that of members of the group known as *Sterculia* B. From examination of material recently come to hand, the final determination of unknown wood specimens from New South Wales and New Caledonia, as belonging to the genus, has been completed. Work is continuing on the woods of Burseraceae and Sapindaceae from the south-west Pacific area, and preliminary plans are in hand for the examination of woods of Verbenaceae and Aeorarpaceae.

(ii) *Bark, &c.*—Specimens of bark of various Myrtaceae have been collected and are awaiting examination. Further hybrid material from a suspected *E. radiata* x *gigantea* was examined, and bark features of both parents were found to be present. These features would not of themselves indicate hybrid parentage but they afford strong confirmatory evidence. The regenerative tissues in eucalypts are being studied.

(iii) *Structure of Pits.*—Examination of the very early stages of pit development in conifer tracheids and wood fibres showed that the membranes have the typical primary wall structure. Preliminary experiments have been carried out on the penetration of various colloidal materials into hardwoods with a view to defining the properties of this membrane. The disposition of the various layers of the secondary wall around bordered pits of conifer tracheids has been determined.

(*c*) *Morphological Aspects of Lignification.*—A study has been made of lignification in the differentiating xylem of *Pinus radiata* and various species of *Eucalyptus* at different times during the growth cycle. In both cases lignification was observed to begin at the cell corners and thereafter spread along the intercellular layer towards the more mature tissue. Observations such as these are consistent with the idea of a centripetally diffusing precursor. However, in primary wood a different condition exists; in the protoxylem the middle lamella zone remains unlignified even after formation of secondary xylem commences. Here, where differentiation is longitudinal, the course of lignification does not agree well with the concept of a diffusing extra-cellular precursor. An overseas worker has reported that lignin may originate by oxidation of the phenyl-propane type precursor in the presence of hydrogen peroxide and peroxidase. Following his work the distribution of peroxidase in various specimens of *Pinus* and *Eucalyptus* has been studied. In general it was observed that in the xylem the peroxidase activity was higher in regions of low lignification (using comparable ultraviolet absorption photomicrographs). Thus, peroxidase activity was high in the zone of differentiating xylem and also in the unlignified intercellular layer and the primary wall in the primary wood of *P. radiata*. The most striking observation, however, was that of intense peroxidase activity in tension wood even in zones far removed from the cambium. Attempts to produce lignification in these areas by culturing in the presence of suitable precursors have not so far been successful. The above investigations have been extended by the study of lignification in *Phormium tenax*, a plant which because of its method of growth, produces excellent material for examination. Here, too, the progress of lignification was complementary to the distribution of peroxidase.

(*d*) *Structure of Isolated Lignin.*—Extremely small fragments of material isolated after treatment of thin transverse and longitudinal sections of *Nothofagus cunninghamii* were examined in the electron microscope. The lignin which is the residue after such treatment appeared to exist in two forms—(i) as a porous foamy structure, in which pores 100-200 Å in diameter were observed, presumably from the cell wall, and (ii) a relatively thick membranous material with no recognizable submicroscopic organization, presumably from the intercellular layer or the primary wall or both. The pores in the cell wall material possibly represent sites originally occupied by the cellulosic microfibrils.

(*e*) *Surface Growth in Plant Cells.*—The concept of multi-net growth of the cellulosic microfibrils in developing cells, as proposed by overseas workers, applies also to coleoptile parenchyma and in no way conflicts with previous conclusions. There remained the problem, however, of demonstrating the site or sites of cellulosic synthesis in the cells. This was done by growing coleoptile segments in solutions of labelled glucose which became incorporated in the cell wall as labelled cellulose. The segments were macerated and autoradiographs prepared from them. These showed a quite uniform distribution of radioactive cellulose over the cell surface, clearly confirming the previous claim of the absence of polar growth.

(*f*) *Low Angle Scattering of X-rays by Wood.*—Attention has been directed to the changes in the scattering diagrams which accompany the shrinkage and swelling of wood, particularly tension wood. Results indicate that the scattering angle decreases on drying and that the initial scattering angle is not attained on reswelling in water. Provisionally, these results—which hold for normal wood to a less exagerated degree—have been interpreted to mean that the micelles aggregate to form larger units in drying and that this change is to a degree irreversible. On swelling beyond the water-swollen dimensions with alkali, the results indicate, as expected, an increased intermicellar distance. Examination by electron microscope of the material appeared to confirm these conclusions.

(*g*) *Bark and Wood Extractives.*—Work has continued on the examination of mangrove tannin extracts in order to assist the development of the cutch industry in New Guinea. Samples of barks from New Guinea species have been analysed for tannin content, with promising results. The value of ***E. astringens*** for plantations has been further emphasized from results obtained from the bark of several specimens five years old grown in Victoria; the tannin content varied between 44 and 54 per cent.

3. WOOD CHEMISTRY.

(Division of Forest Products.)

(*a*) *Lignin and Related Compounds.*—By utilizing knowledge gained in the investigation of residual lignin in pulps, a spectrophotometric method has been developed for the determination of lignin in eucalypt pulps. This is simple, rapid, and applicable to low lignin contents for the determination of which the ordinary chemical methods are unreliable.

The distribution of two fractions of methanol lignin and of the various impurities associated with them after resolution in a Craig machine has been determined by quantitative chromatography. The results show distribution curves of the various impurities to be distinct from those of the lignin, but there is still considerable overlap between some impurities and the lignin of high R_F value. The distribution of the latter was rather broad and suggestive of a group of substances rather than a ingle substance. The lignin of low R_F value appeared o be almost completely free from impurities, and a small pecimen has been recovered as a white solid.

(*b*) *Heterogeneous Hydrolysis of Wood Polysaccharides.* —The dissolution of "holocellulose", during hydrolysis with several concentrations of sulphuric acid between 0.01 and 12 per cent., shows a temperature coefficient, per 0° C., of 3.4 ± 0.1. The constancy of this coefficient, or all the concentrations of sulphuric acid used, indicates hat a change in mechanism from reaction to diffusion control, during the dissolution of the amorphous polysaccharides, is highly improbable.

(*c*) *Chemistry of Tension Wood.*—Composite specimens of tension wood, the wood opposite the tension wood, and the side wood, from four trees of *E. goniocalyx*, have been analysed. As with other specimens of tension wood, that from this species was found to have a high α-cellulose and low lignin content in comparison with the other samples examined. When the results are expressed in terms of a given amount of lignin, the tension wood shows abnormally large amounts of polysaccharide which is richer in galactose residues than are the "opposite" and "side" wood polysaccharides. The ultraviolet absorption spectrum of tension wood lignin showed the characteristics of mature wood lignin to a greater extent than did those of "opposite" and "side" wood lignin. This may indicate the earlier arrest of lignification in tension wood.

(*d*) *Pulping of Tension Wood.*—Chemical pulps prepared from the tension wood of specimens of *E. regnans* and *E. nitens* were inferior in properties to those from normal wood of the same species, the poorest pulps being obtained from the tension wood with lowest lignin and pentosan contents. Pulps prepared by mechanical means showed the opposite trend, the quality decreasing as the lignin and pentosan contents of the tension wood approached those of normal wood.

(*e*) *Mechanism of Delignification.*—Investigations of the mechanism of alkali pulping under conditions of constant temperature and sustained alkali concentration during cooking have been completed. The rate of change in yield and the rates of lignin and pentosan removal could not be fitted to a rate equation of any integral order. Temperature had the greatest influence on delignification, pentosan removal, and cellulose loss. At any given temperature, delignification was controlled mainly by the concentration of the cooking liquor, while the pentosan removal was governed mainly by the total amount of alkali used regardless of time concentration and flow rate; the cellulose loss was almost independent of everything but time.

(*f*) *Pulping of New Guinea Timbers.*—Pulps have been prepared from *Araucaria klinkii* by the following processes: neutral sulphate, high-yield sulphate, kraft semi-chemical, and cold soda. The last-named process gave poor-quality pulps, but the others produced pulps comparable with those from the northern hemisphere papermaking species treated by the same processes. The kraft semi-chemical pulp had a much higher tearing resistance than those from the other processes. Veneer waste from *A. klinkii* was pulped by the sulphate process giving a high strength pulp similar to those made from hand-made chips of the same species. Cold soda pulps have been prepared from species of the mangrove association and from *eucalyptus deglupta*. One of the species from the mangrove areas, viz. *Excoecaria*, produced a very satisfactory grade of pulp.

(*g*) *Semi-chemical Pulping of Eucalypts.*—The cold soda process has been examined in some detail for *E. regnans*. Increased concentration and temperatures gave slightly faster penetration, but complete penetration was not necessary to give a satisfactory pulp on subsequent defibration. An alkali concentration of 2 per cent. at room temperature applied for a period of 4 hours gave a satisfactory pulp.

(*h*) *Interfibre Bonding.*—Properties derived from stress-strain curves are now used as a routine measurement of interfibre bonding. Pretreatment of papermaking fibres with the various swelling agents was found to influence the interfibre bonding capacity. Swelling changes the fibre structure and with it the number of hydroxyl groups available for interfibre bonding. Vapour pressure history does not exert an influence on the rheological behaviour apart from that of the total sorbed water.

(*i*) *Mechanism of Beating.*—The nature of the changes produced on beating fibres was investigated by varying swelling properties. This was done by substituting the hydroxyl groups to various degrees, using substituent groups of different sizes, before beating. The results supported theories which postulate that swelling and hydration are the essential changes on beating. An increase in the interfibre bonding capacity of lightly beaten fibres at low degree of substitution can be correlated with the trend in swelling capacity. No initial rise in bonding capacity was observed for well-beaten fibres; this showed that the substitution effect for unbeaten fibres partly simulates the beating process. For a constant degree of substitution propionylation is more effective than acetylation in reducing interfibre bonding.

(*j*) *Cellulose Reactivity.*—Factors influencing the rate of reaction of the hydroxyl groups of fibrous cellulose have been studied. The density of the hydrogen bond network appears to be a major underlying factor in the reactivity of cellulose in any solid form. Attention has been paid to the kinetics of acetylation, which can be interpreted either on the basis of simultaneous diffusion and reaction in a microheterogeneous system or in terms of the accumulation of reaction products in a quasi-homogeneous system. The rate at which the hydrogen atoms of the hydroxyl groups of a cellulose film can be exchanged for deuterium when the film is exposed to heavy water vapour has been examined by infra-red methods.

(*k*) *Papermaking Properties of Thick-walled Fibres.*—Throughout the world and particularly in tropical regions there are large quantities of timbers with thick-walled fibres, the papermaking qualities of which are not satisfactory for many purposes. In order to improve these qualities and to make the fibres more generally valuable, attempts have been made to modify the fibre structure by physical methods, but these proved unsatisfactory because they resulted in loss of paper strength. Attention has therefore been directed towards fibre modification by chemical means. The treatment found most promising in the case of the thick-walled late wood tracheids of *Pinus taeda* has been suspension of lightly beaten fibres in dilute (0.1 per cent.) sodium hydroxide. Considerable improvement in pulp strength properties has been obtained. Application of this treatment to thick-walled fibres of hardwood origin is being investigated fully, although some preliminary results with a mangrove (*Rhizophora apiculata*) were not encouraging.

4. TIMBER PHYSICS.

(Division of Forest Products.)

(*a*) *Sorption Studies.*—During the year further tests have been made on the sorptive and wetting characteristics of klinki pine. The effect of temperature on the sorption isotherm has been extended to two additional temperatures, 10 and 55° C. These confirm the earlier indications of a decrease in the extent of hysteresis with increasing temperature. Differential heats of sorption calculated from the adsorption isosteres agreed reasonably well with those obtained earlier from calorimetric measurements. An investigation of the effect of particle size on the heat of wetting showed that the heat evolved on wetting dry klinki pine increased from 18.9 cal./g. for unground wood to 20.6 cal./g. for wood passing 60 mesh size.

Measurements have been commenced on the sorption characteristics of components isolated from *Eucalyptus regnans*. Preliminary work on unmatched material had shown that the heat of wetting varied from 36 cal./g. for the non-cellulosic polysaccharide fraction to 8 cal./g. for methanol lignin. However, the heat of wetting of lignin varied markedly with the method of preparation; the values for Klason and periodate lignin being approximately twice that for methanol lignin. In addition, heat liberation from methanol lignin persisted for up to an hour, whereas, with all the other fractions tested, heat liberation was complete within a few minutes. The heats of wetting of all constituents were found to be approximately proportional to their equilibrium moisture content at 65 per cent. relative humidity.

In the tests on fractions, wetting from a number of initial moisture contents enabled the differential heat of sorption to be calculated. It appears that the differential heat of sorption of the Klason lignin is lower at low moisture contents than that of the cellulosic constituents, namely, holocellulose and the cellulosic polysaccharides.

Concurrently with the wetting studies, sorption isotherms of the same materials are being determined. On adsorption, the equilibrium moisture content of the Klason lignin was less than that of the wood, but on desorption the values were nearly the same over a considerable portion of the isotherm, i.e., the moisture content hysteresis of the lignin was greater than that of the entire wood. Isotherms for the remaining constituents have not yet been completed.

(*b*) *Shrinkage and Density Measurements*.—The study of the dimensional stability of insulating boards has been completed. The variation between the equilibrium moisture contents of the different makes of boards was considerably less than for the hardboards. The length swelling of the insulating boards was of the same order of magnitude as that of the hardboards, but that in thickness was only a little over half as great.

Shrinkage and density tests have been completed on material from 106 Australian species, for many of which no data were previously available.

(*c*) *Creep and Related Phenomena*. (i) *Creep Measurements*.—Measurements on 27 beams of blackbutt, which have been under load for eighteen months in the open air, have shown that creep in initially green material allowed to dry during test is considerably greater than creep in material kept green. This has been evident also in sixteen beams of mountain ash which has been under load indoors for a period of five months.

An air-dry beam of mountain ash has been under load for seven months at an extreme fibre stress of 5,000 lb./sq. in. in a room controlled to 35° C., and strain measurements have been made at various points across the depth of the cross section. The distribution of the strain has been found to remain linear during the period of test although the deflection of the beam has increased appreciably.

Increases in strain from 20 to 140 per cent. have occurred in specimens of green mountain ash loaded in compression for almost three years at stresses ranging from 10 to 35 per cent. of the short-time strength. No measurable creep has occurred in specimens loaded to 6 per cent. of the short-time strength.

(ii) *Factors Affecting Creep*.—Further tests on the influence of stress on creep in tension indicated no significant departure from proportionality at temperatures up to 50° C. and stresses up to 10,000 lb./sq. in. in tension.

(iii) *Failure under Continuous Loading*.—Specimens of green blackbutt have been loaded in compression and shear, at stresses ranging from 60 to 100 per cent. of the short-time strengths, to study the relationship between stress and time to failure under continuous loading. All specimens failed in less than 29 days, but a considerable scatter of results occurred at each stress. The mean time to failure at the lowest stress was nine days for compression specimens and fourteen days for shear specimens. These times decreased markedly with increasing stress.

(*d*) *Vibrational Properties*.—An apparatus has been designed and built for the measurement of the elastic properties of wood at very low (subaudio) frequencies. Theoretical relations have been derived for the arrangement and have been verified by experiment. Measurements taken on the apparatus are designed to provide information linking the results of dynamic tests at audio frequencies with those of static tests. Sensitivity and reproducibility have been found to be satisfactory.

(*e*) *Electrical Resistance Moisture Meters*.—Species correction figures for electrical resistance moisture meters are now being measured up to 40 per cent. moisture content instead of 24 per cent. because of the increasing use of higher-range meters. So far the extended range of corrections has been established for nine species.

5. TIMBER MECHANICS.

(Division of Forest Products.)

(*a*) *Studies of Properties and Testing Methods*.—The investigation of variation of modulus of rupture in mountain ash specimens cut at various angles to the grain was continued. Similar tests were made on 3/16- and ¾-in. plywood of hoop pine, mountain ash, and rose gum.

Tests continued on yellow box, red stringybark, and messmate stringybark specimens loaded to produce compression failures in bending, then loaded on the opposite face to failure. No significant reduction in ultimate strength caused by the first loading was apparent. The effect on toughness of preloading in bending was investigated on samples of Sitka spruce and messmate stringybark.

(*b*) *Species Testing*.—Standard mechanical tests on Australian timbers were continued. Thirty-eight species were sampled, including two from Queensland, five from New South Wales, 28 from Victoria, one each from South Australia and Western Australia, and one from New Britain. Timber from 47 trees was tested green and from 41 trees air-dry. A bulletin on the mechanical properties of 100 Australian and New Guinea species has been completed for publication.

(*c*) *Silvicultural Tests*.—Compression and bending tests were made on *P. radiata* representative of various age classes and growth conditions. The strength/age relationship for two-year-old trees contrasted with the 10, 30, and 40 year old material from South Australia. Ten trees of *P. pinaster* and twenty trees of *P. radiata* from Western Australia, including some treated with zinc sulphate and showing a subsequent marked increase in growth rate, were studied. Microtension specimens cut from trees which exhibited both normal and abnormal rates of growth were taken from early wood and late wood. These showed that the strength of early wood, and also that of late wood, considered separately, were independent of the rate of growth and silvicultural factors. The strength of timber in specimens including a number of growth rings apparently is related to the percentage of late wood rather than to variations in strength of early wood or of late wood respectively.

(*d*) *Timber Construction*.—(i) *Structural Design*.—Various structural designs have been developed. Novel structures have been tested, including light-framed tied-arch trusses, light-trussed purlins, box-section roof girders with hardboard glued to timber frames, and various composite concrete timber beams using *P. radiata* thinnings. Interim working stresses for *P. radiata* were issued. A new edition of the *Handbook of Structural Timber Design* is being prepared.

(ii) *Connectors*.—After nine years, long-duration tension tests on split-ring and shear plate connector specimens of three species are being discontinued. Intermittent loading tests extending over three months were made on a representative group of these, and provided a valuable check on experimental errors of the full-scale investigation. All specimens, except a few consolidated into a continuing test group, are being loaded to immediate failure. In every case, the maximum short-duration load was several times the long-duration load.

Testing of nailed pressed steel connectors for use with building scantling is complete. Connectors of several types were attached to timber nailed green and tested green, and others to timber nailed green and tested after drying to 12 per cent. moisture content.

(iii) *Nails.*—Static and impact withdrawal tests, both at the moisture content as driven and when dried to 12 per cent. over a period of three months, were made using case nails in karri and mountain ash. Similar tests were made using building nails driven into green messmate stringybark and withdrawn at 12 per cent. moisture content after drying for twelve months. In green messmate stringybark, tests were made on joints with various numbers of nails, and comparisons made between joints loaded perpendicular and parallel to the grain, and allowed to dry after nailing.

(iv) *Glued Joints.*—Glued joints were studied in double-lap tension splices, and the magnitude and distribution of lateral stresses with varying joint geometry measured. Tests were made also on box-beams with hardboard webs to obtain estimates of maximum shear stress developed in webs, and between glued areas of flanges and webs.

(v) *Columns.*—During the year 47 columns of mountain ash, yellow stringybark, and Douglas fir, at various moisture conditions and having various slenderness ratios and loading eccentricities, were set up under long-duration loading. To date, 337 have been erected and 253 have failed in periods ranging from a few hours to several years. The more slender columns continue to survive for longer periods than the shorter columns. Eucalypt columns, more than Douglas fir, are liable to failure in the green condition and during their drying-out period. For the three species in the green condition, 91 per cent. of the mountain ash columns have failed, 78 per cent. of yellow stringybark, and 67 per cent. of Douglas fir. Of those erected green and drying under load, the failures totalled 84 per cent. each for mountain ash and yellow stringybark and 56 per cent. for Douglas fir. Columns erected dry are too few for analyses.

(vi) *Scantling Grading.*—Studies of reduction in strength due to various grading defects in jarrah scantling were continued on the 4 x 2 inch size.

(vii) *Plywood.*—Strength tests are being made on karri plywood for use in engineering structures.

(viii) *Poles.*—Because of lack of information on the strength properties of poles of species currently being used in Australia, an investigation has been undertaken on a number of species and pole size classes tested over a span of 30 feet and loaded in bending. Other tests are being made on clear material from various positions in the poles to establish correlations between full pole tests, clear matched material, and species standard test values otherwise determined. Tests have been completed on 89 green messmate stringybark poles and on matched small clear specimens. Preliminary analyses of half this sample indicate that the main strength properties of the pole sections do not vary with size classes. However, the strength of clear specimens taken from the top section of the pole appear to be significantly different from those samples near the bottom. No correlations between the groups of clear specimens taken separately or together and the full pole strength values have yet been established.

(*e*) *Growth Stresses in Trees.*—Measurements of longitudinal growth stress were made on three logs of messmate stringybark and two of silvertop ash, representative of several age classes. Growth strain recovery after release of growth stresses as a result of cross-cutting was studied on one log of each species. In one tree of very eccentric growth and containing macroscopic compression failures, extreme patterns of stress recovery were evident.

6. TIMBER PRESERVATION.

(Division of Forest Products.)

(*a*) *General.*—In addition to a large volume of advisory work, much time has been spent in inspection and demonstration of field tests, treatment of timber for test purposes and demonstration of treatment methods, assistance to industry in design of treatment plants, lectures, and training of students from abroad.

(*b*) *Field Tests and Surveys.*—Inspections of field and service tests of preservative treated sleepers, poles, and fence posts were made in Western Australia, Victoria, and New South Wales. These tests involved inspection of more than 3,000 specimens in fifteen different localities. In particular, the pole tests attracted considerable attention and more than 100 visitors, mainly pole engineers, were present at the inspections.

New tests installed during the year include a service test of treated crossarms in Victoria and of pine sleepers in South Australia and two field tests of treated specimens for the Swedish and Finnish Forest Products Laboratories. Also, a large-scale test of new preservatives is now being prepared in which several thousand small treated specimens will be installed in various sites in Australia and New Guinea.

During the year, two surveys were conducted to gain information on aspects of termite and decay damage in buildings.

(*c*) *Preservative Treatment of Fence Posts.*—A bulletin describing and illustrating simple methods for treatment of round fence posts, suitable for use by the farmer, was issued during the year and more than 20,000 copies distributed. In addition to radio and press publicity, demonstrations were given at about sixteen country centres and involved the treatment of several thousand posts provided by farmers for this purpose.

The low-pressure treatment method developed by the Division and the portable plant for its application have attracted considerable interest abroad. Plans and specifications for this unit have been supplied to numerous inquirers.

(*d*) *Crossarms.*—The considerably increased life to be expected from application of modern preservative treatments to eucalypt poles has focused attention on the corresponding need to increase the life of the crossarms. Because of the importance of mechanical failure of arms owing to weathering, preservative oils are considered most suitable. This, however, has raised the problem of cleanliness, and current research has aimed at developing a high-pressure oil treatment which will give maximum cleanliness in subsequent handling of the treated arm.

(*e*) *Diffusion Treatments of Green Timber.*—Methods for the diffusion treatment of green timber have been further investigated, with particular reference to the problem of utilizing non-durable timbers for building purposes in tropical areas. As many of these timbers are difficult to penetrate in the heartwood by conventional pressure methods, diffusion treatments offer an attractive alternative provided treated timber is reasonably protected from leaching in service. A successful process has been developed, and is now in commercial use in New Guinea, for treatment of klinki pine building timber. It involves momentary dip treatment of green timber in a highly concentrated preservative solution followed by block stacking to permit diffusion of chemicals into the wood.

Treatment of refractory building timbers is also being studied to determine whether satisfactory penetration can be obtained with a combined pressure-diffusion treatment.

Diffusion treatments of plywood, by dipping green veneer in preservative salts followed by block stacking, have been further investigated. Treatments previously tested for resistance to termites have now been tested against decay fungi. Sodium pentaborate, which gave good results in termite tests, proved very satisfactory in decay tests when compared with a number of recognized preservatives.

(*f*) *Mycological Work.*—Suitable techniques have been developed and work is now in progress to examine toxic extractives which are responsible for the durability of Australian timbers. Work is at present limited to a study of extractives responsible for decay resistance in eucalypts. The method adopted is to extract the durable timber successively with various solvents and after each extraction to determine loss in durability. Simultaneous tests are made to determine the toxicity of the extract when incorporated into a non-durable timber.

An important aspect of mycological work has been the laboratory testing of decay resistance of treated and untreated timber by the soil-jar technique. This work has included systematic testing of the natural decay resistance of Australian timbers and its variation within the species. It has also included tests on the toxicity of various preservatives before and after prolonged leaching in water of varying pH.

Collection of Australian and New Guinea wood-destroying fungi has continued, and five new species have been discovered.

(*g*) *Timber Borers.*—In addition to work on the toxicity and permanence of preservatives to *Lyctus brunneus*, tests are continuing to determine the susceptibility to this borer of 90 Australian timbers which are not yet commercially used.

(*h*) *Miscellaneous.*—Other work has included studies on deterioration of timber in cooling towers, prevention of decay in external window joinery by dip treatment in water-repellent preservatives, pressure treatment tests on various New Guinea timbers, and an investigation of the effect of treatment with water-borne preservatives on the drying rate of timber.

7. TIMBER SEASONING.

(Division of Forest Products.)

(*a*) *General.*—Because of the growing importance of plantation softwoods in Australia, emphasis was given to the design of drying equipment and plant for this material. Request for advice increased to a level even higher than that of last year.

(*b*) *Collapse.*—Studies on the mechanics of collapse and recovery were continued. The influence of surface tension, dissolved materials, nuclei, temperature, and time on the magnitude of collapse-inducing forces was examined. The effects of drying stresses and set are to reduce collapse in width but to increase it in thickness, both effects being intensified by steep moisture gradients. Absorbed inorganic salts were shown to affect collapse behaviour only if the treatment involved a chemical change. It was shown that irrecoverable collapse is increased by reconditioning at moisture contents greater than fibre saturation point.

(*c*) *Drying Studies.*—Studies of economic treatments to reduce log and pole degrade during storage, and to protect air drying stacks of sawn timber, were commenced. Progress was made with work to relate optimum spacing for air seasoning stacks with yard turnover and drying cost.

Studies on combined vapour drying and high-pressure preservation treatment for five difficult Australian sleeper timbers were completed, and sections placed for exposure tests. The effect of treatment with several water-borne preservatives on the drying rate of radiata pine was examined; for most of the Australian material drying time for the salt-treated timber approximated 20 per cent. more than for controls either untreated or pressure treated with water only.

Exploratory studies aiming at relating the drying behaviour of yard-built seasoning stacks to small laboratory plaster models were commenced as a first step in using the models to simulate field conditions on a laboratory scale. Work was commenced to determine critical heating conditions for peeler blocks of alpine ash and messmate stringybark in relation to dried veneer quality; for veneer peeled at 140° F. gross shrinkage on drying ranged from 10 to 30 per cent. more than for cold peeled material. Studies on veneer drying schedules were continued. Further kiln schedule work for sawn timbers was completed on Tasmanian alpine ash, radiata pine, yellow stringybark, keruing, and coigue.

(*d*) *Equilibrium Moisture Content.*—A study to measure equilibrium moisture content (e.m.c.) conditions for the timber work of houses, bridges, harbour installations, ships' parts, and poles was commenced. An e.m.c. survey in Antarctica was initiated through the co-operation of the Antarctic Division of the Department of External Affairs. Work on the moisture content of railway sleepers in the track was continued. Studies to relate e.m.c. to meteorological data were resumed.

(*e*) *Kiln Design and Equipment.*—Roller and mesh belt veneer driers of American and European manufacture were tested. Kiln heating with flue gases was examined. Design data were prepared to enable the several batteries of obsolete kilns to be reconstructed. New kiln handling equipment was designed, and kiln control panels were redesigned to permit rapid interchangeability of manual and automatic systems. Charts were prepared to enable the rapid selection of optimum kiln fan size to be made in terms of capacity per unit of power demand.

Kiln designs for sawn timber, veneer, plywood, case- and core-stock were prepared for 52 firms and research organizations in Australia, the United Kingdom, South Africa, the United States of America, France, Holland, and Austria; approximately 430 drawings were issued. One hundred and six visits were made to seasoning plants in all Australian States, New Guinea, and New Zealand to advise on kiln installation, veneer drying, handling equipment, flush door manufacture, prevention of warp, plant efficiency, kiln control, reconditioning, kiln maintenance, predrier operation, steam generating equipment, and stacking.

Plant layouts were prepared for eight firms. The combustion characteristics of McCashney burners were further analysed and a new design prepared to give approximately double the disposal capacity of the previous largest; designs were issued to 39 firms in Australia, New Guinea, the United Kingdom, New Zealand, South Africa, Singapore, and Sarawak.

(*f*) *Veneer and Gluing Studies.*—Logs of alpine ash, mountain ash, klinki pine, radiata pine, hoop pine, and coachwood were peeled and studies made on lathe control settings.

Progress was made with tannin formaldehyde glue studies. The effects of urea formaldehyde, phenol formaldehyde, and polyvinyl acetate additives were examined, and techniques for controlling viscosity and spreading qualities were studied. Work to improve wet and dry joint strength was commenced.

Studies to improve the bonding of boron-treated veneer with phenol formaldehyde resins were resumed, and work on the gluing of tempered and standard hardboard was completed. The influence of veneer thickness, moisture content, and glue variables on rate of temperature rise at the glue lines of klinki pine plywood was investigated. The behaviour of doors manufactured with face veneers at right angles to door length was studied. Work on chniques for end-grain gluing was commenced. An xperiment to determine the application of resonant equency techniques for testing plywood bond strength as continued.

8. TIMBER UTILIZATION.

(Division of Forest Products.)

(*a*) *Timber Uses.*—Information was supplied on the uitability of timbers for 105 uses, and advice given on he properties and uses of 112 species. Several inquiries ere dealt with concerning timber production and onsumption generally in Australia.

(*b*) *Manufacturing Processes.*—The Division's influence n saw-milling continued to expand as indicated by the equests for information on plant, and for assistance with ractices. Designs were prepared for seven new sawnills, two resaw plants, a planing mill, two distributing ards, a door manufacturing plant, a joinery works, and a urniture factory. Problems related to breaking-down roduction sawing, resawing, and quartersawing were iscussed. Information was made available on log oaders, loading tongs, logging arches, cable riggings for og sorting, log cranes, barkers, breaking-down saws, log dgers, frame saws, bolters, bandmills, breast benches, ydraulic drives for log carriages and breast bench rolls, utomatic docking saws, sorting tables, planers, waste onveyors, pneumatic sawdust extractors, hogs, chippers, ark disintegrators, and several woodworking machines. Advice was given on the manufacture of cases, flush doors, hardboards, laminated artificial limbs, lattice laths, aminated skis, parquetry, shoe heels, wood flour, woodwool, and wood-wool building boards; on the finishing of flooring, weatherboards, cabinet woods, boat decks, and bench tops; on bleaching and removal of stains; and the curing of squeaks in floors.

(*c*) *Waste Utilization.*—The effect on soil-water relationships of incorporating fresh and partially hydrolysed sawdust in field plots was investigated, a tension table being used. After twelve months there was evidence of an increase in water holding capacity due to added sawdust, but no significant improvement in structure. At eighteen months, growth of grasses on plots treated with sawdust and nitrogen had overtaken the corresponding controls. This accompanied improved nitrogen availability as shown by measurement of nitrate.

Laboratory incubation studies were commenced to investigate some of the major factors affecting rate of decomposition of sawdust mixed with soil and were followed over a period of six months. A complete nutrient solution was applied, but despite generally favorable conditions, decomposition was not as rapid as expected. Decomposition proceeded faster in the lighter soil. There was evidence of interactions between the effects of wood species and limestone, and of wood species and extractives. The effects of these factors on species composition and activity of the soil flora are also being investigated.

The decomposition of wood waste by fungi was examined, particular attention being given to methods of increasing susceptibility to attack by microfungi. The water and alcohol extractives of *Eucalyptus regnans* were found to largely inhibit growth of *Chaetomium globosum* and a number of other species. The addition of nutrient salts in moderately high concentration and several chemical treatments increased rate of decomposition appreciably. Partial delignification and treatment with dilute alkali were most effective. At the concentrations used, alkali removed very little lignin and the treatment was as effective at 25° C. as at 100° C. The extent to which the accelerated decomposition is due to breaking of lignin-carbohydrate bonds or to extraction of toxic substances is being investigated.

Information was made available on the general uses of sawdust and shavings, sawdust burning for steam production, briquetting of sawdust, sawdust-resin boards, sawdust for bowling greens and coursing tracks, and manufacture of small wooden articles from wood residues.

(*d*) *Sawing.*—The studies to determine the power consumption on typical breast benches in Victorian hardwood sawmills were continued, and it has been demonstrated that more efficient sawing on No. 1 breast benches is obtained when feed speeds are varied with depth of cut. Investigations with sawing chains were continued, together with slow-speed measurements of cutting forces on single teeth. The construction of a pendulum dynamometer to be used to study the cutting action of single teeth was completed.

(*e*) *Standards.*—Collaboration with the Standards Association of Australia was continued in the preparation and promulgation of timber standards. Chairman's duties were continued for Sectional Committees on Wood Technology, Timber Utilization, and Portable Ladders functioning under the Timber Industry Committee, and technical services rendered in drafting and reviewing standards. During the year grading rules for wood blocks for parquetry flooring, a code for laying parquetry flooring, and grading rules for engineering structural timbers were drafted; grades for sawn hardwoods and south-eastern Australia and milled flooring were revised; a draft standard for portable timber ladders was reviewed; and precommittee discussions were held regarding specifications for house stumps, sole plates, fence posts, sills, wooden shingles, softwood scantling, door stock, and waterproof plywood.

XV. BUILDING.

1. GENERAL.

The building research work of the Organization is undertaken mainly by the Division of Building Research, Highett, Victoria, which collaborates closely with the Commonwealth Experimental Building Station of the Commonwealth Department of Works in New South Wales. Research is directed towards the study of the more effective use of available materials, the adaptation of traditional materials to new constructional methods, and the development of new materials and building techniques for the improvement of both the functional aspects of buildings and the efficiency of methods of construction. The work of the Division is reported in this chapter.

Work on timber for constructional purposes is concentrated in the Division of Forest Products (*see* Chapter XIV.). Work on building foundations is undertaken by the Division of Soils (*see* Chapter II., Section 7), and work on cement and ceramics by the Division of Industrial Chemistry (*see* Chapter XVIII., Section 3).

Division of Building Research.—As in the previous year, the work of the Division was severely hampered by the great difficulty in recruiting staff to fill vacancies at all levels. However, research on bituminous materials, particularly their application to flat roof construction, has been intensified with the return of an officer, who had spent two years in England, Europe, and the United States of America, where he obtained training and experience in the chemistry and technology of bitumen. An appointment has recently been made for investigations of the problems of the fibrous plaster industry.

There is an increasing awareness by the building industry of the value of research, and the paint industry has agreed to contribute £2,500 per year for a minimum of three years towards the cost of an investigation into the problems associated with the painting of plaster surfaces. Negotiations are in progress with the Australian Clay Products Association for an extension of the Division's work on clays and clay products. The Master Builders' Association of New South Wales is co-operating with the

Division and the Building Research Liaison Service of the Department of Works is conducting full-scale field trials of lightweight plaster.

An informal meeting of the Directors of the building research organizations of the British Commonwealth and the United States of America was held in Australia in April. This meeting, the second of its kind (the first being held in London in 1951), served a very valuable purpose in enabling the Directors to interchange ideas and to co-ordinate their activities, so ensuring the most effective use of the limited staff and facilities available in the various countries represented.

2. LIGHTWEIGHT AGGREGATES.

(Division of Building Research.)

(*a*) *Expanded or Bloated Clays and Shales.*—Bloated clay and shale aggregate are not yet being manufactured in Australia, but the Division is firmly convinced that they can and will play an important part in the Australian building industry. Consequently, research on their production and properties is being continued. Tests on raw materials from several areas have been made, and arrangements are in hand for an extended investigation of South Australian clays and shales in co-operation with the South Australian Department of Mines. Shale from the Adelaide area has been processed into "Haydite" (crushed) type and coated type aggregate, the latter giving the better results in concrete.

(*b*) *Perlite.*—Experimental work has been concentrated on the chemical and physical properties of perlite ores and their expanded products and on the relationship of these properties to the behaviour of perlite as an aggregate.

Investigations in the pilot plant have shown that excellent aggregate can be made from many of the ores examined to date, but manufacturing techniques must be adjusted to suit the characteristics of the different ores. So far, examinations have been confined to samples of ore provided by manufacturers or potential manufacturers.

Considerable attention has been directed to the studies of the secondary expansion of plasters containing perlite. The likely effect of such behaviour on structures is being observed by examination of two ceilings, one full scale and the other an experimental laboratory panel, of perlite plaster on gypsum board attached to steel battens. No deformation or bending between battens has been observed with the full-scale ceiling, and only very slight deflections of the order of 1/100th inch between the battens at 4-ft. centres in the laboratory panel have occurred.

3. CONCRETE INVESTIGATIONS.

(Division of Building Research.)

(*a*) *Theory of Rupture of Concrete.*—Microcracks have been observed to form in concrete in tension at stresses well below the ultimate, and the object of experiments at present in progress is to assess their influence on the behaviour of the concrete. The first series of tests on concrete beams held at loads of 90, 50, and 20 per cent. of the predicted ultimate load for 400 days indicated that the formation of pre-failure microcracks is unlikely to lead to failure under sustained high loading.

(*b*) *Shrinkage and Cracking Studies.*—The preliminary tests of the effect of carbon dioxide on mortars have been completed, and an examination of the interaction between moisture in the concrete and carbon dioxide was begun. For the second phase of this work concrete specimens were cured for one week in water and then for three weeks in air or carbon dioxide at some specific humidity.

The results for strength and shrinkage are not in complete agreement with the results of earlier tests, and although it has been found that the carbon dioxide treatment reduces the shrinkage and increases the strength, the effect is not as great as in earlier work. The problem is therefore being investigated further and some of the earlier work repeated.

The cracking susceptibilities of cement mortar mixes with various water/cement ratios, curing conditions, degrees of restraint, and gauge length have been studied. The specimens in the form of bars were restrained with steel rods on the longitudinal axis. From the contraction of the steel rods the tensile stress developed in the mortar by shrinkage was calculated. From this work it was found that the lower the water/cement ratio, the earlier the cracking occurred.

(*c*) *Cellular Concrete.*—The work on the lightweight cellular concrete, foamed calcium silicate, has been concerned largely with the examination of the strength characteristics of this material, particularly with regard to the effect of curing in saturated steam. Maximum values of the strength/weight ratio were reached after curing at about 180° C. Calcium silicate concrete made with silica flour having a very high specific surface area was found to have a strength/weight ratio considerably lower than that made with silica of smaller surface area.

4. GYPSUM PLASTER AND PLASTER PRODUCTS.

(Division of Building Research.)

(*a*) *Fundamental Research—the Setting Process.*—The study of the initial stages of the hydration of calcium sulphate has been continued by a combination of thermogravimetric analysis, differential thermal analysis, and X-ray diffraction. This has shown that, when plaster (calcium sulphate hemi-hydrate) is mixed with water, gypsum begins to form well before the time of the initial set; e.g., for a plaster with an initial setting time of 33 minutes, no gypsum could be detected after 13 minutes, but at 24 minutes, 3–4 per cent. was present, and at 33 minutes, 7–8 per cent. Hence the gradual thickening of the slurry which produces the initial set is accompanied by the formation of gypsum crystals. It seems probable therefore that the formation of these crystals at least contributes to the production of that thickening.

Examination of the progress of the hydration of calcium sulphate has shown that although the bulk of the hydration takes place in about three hours the process may continue for several days before it is complete. This is important, because a plaster product if dried before it is completely hydrated may be damaged by disruptive expansion if hydration recommences on subsequent wetting or exposure to moisture.

The effect of added inorganic salts in accelerating the setting process is now being examined. There is some evidence of the formation of double salts with the calcium sulphate.

(*b*) *Pilot Plant.*—The calciner for the pilot plant that is being constructed to facilitate investigations into the dehydration of gypsum is almost complete, and a patent application to cover the principles involved has been filed. Experimental work on the removal of free water from the washed gypsum prior to its entering the dryer has shown that the usual drainage bins and the gypsum handling associated with their use can be eliminated by blowing the wet gypsum up a perforated duct into a cyclone which forms portion of the flue of the dryer.

(*c*) *Structural Gypsum.*—Work on gypsum plaster used as a structural material has been associated chiefly with its behaviour under long-term loads and under conditions of changing temperature and relative humidity, and with the study of its compressive strength under different conditions of storage.

Under long-term loads the phenomenon of creep occurs, and the creep strains in reinforced plaster beams under constant loads, from the cracking load downward, have been measured by electrical resistance strain gauges. Results so far demonstrate that, in the early stages, the creep strain is a linear function of time and load.

The Victorian Uniform Building Regulations specify, as a quality control, a minimum two-hour wet strength for structural plaster, but, as there was some evidence at the strength of plaster kept wet decreases with time, e variation of compressive strength according to the orage conditions was examined. After 50 days in fog nditions the wet strength was roughly 35 per cent. wer than the two-hour wet strength, and this behaviour hich was shown to a lesser extent at the earlier stages dicated that structural gypsum should, from the point view of strength, be dried out as quickly as possible ter casting.

5. LIME AND LIME PRODUCTS.

(Division of Building Research.)

(*a*) *Correction of Unsoundness in Magnesian Limes.* –Much progress has been made in the study of the ystem MgO-$MgSO_4$-H_2O, which parallels that of the ystem MgO-$MgCl_2$-H_2O previously studied in connexion ith its importance in the correction of the unsoundness f magnesian limes. The efficacy of the chemical method removing unsoundness from a commercial lime has een demonstrated in a series of plastered panels in the aboratory. Untreated panels showed, after three months, 0 to 70 pits per square yard, whereas panels in which -4 per cent. of calcium chloride was added are still free rom pits.

(*b*) *Sand-lime Bricks.*—Advice and assistance has con-inued to the two established sand-lime brickworks in Victoria, to two that have recently commenced pro-luction in Western Australia, and to one in South Aus-ralia still in the planning stage. Tests on the raw naterials and products have been carried out for one of he Western Australian manufacturers.

6. CLAYS AND CLAY PRODUCTS.

(Division of Building Research.)

(*a*) *Clay Research.*—(i) *Regional Studies of Australian Heavy Clays.*—An examination of the clays and shales used in brickmaking in the Perth area was started. No significant differences are apparent so far in the qualitative mineralogical examination of the Swan River and Canning River clays.

(ii) *Expansion of Clay Products.*—The study of the expansion of clay bricks on exposure to moisture has continued. Measurements on kiln-fresh bricks from Melbourne yards continue to show expansions over several cycles for bricks soaked in water and dried, and for over 300 days for those standing in air in an air-conditioned laboratory. Expansions of experimental brick walls erected from bricks respectively " kiln-fresh ", " as delivered ", and " soaked " (for five weeks) are being measured also. For each type of brick the effects of three types of mortar—1:4 cement/sand; 1:1:6 cement/lime/sand; and 1:3 lime/sand—are being studied.

Kiln-fresh bricks have expanded the most, soaked bricks the least; slight differences only are apparent for the different mortars.

(iii) *Deterioration of Clay Roofing Tiles.*—The deterioration of clay roofing tiles, particularly in sea-front areas, is a problem that is becoming more evident and is one that appears to be related to the expansion noticed with clay bricks. Deteriorated tiles have been examined mineralogically and chemically, and so far there does not appear to be any significant difference in the soluble salts in the affected and unaffected parts. However, a study of the effects of alkalis on the rehydration and thus on the expansion and possibly on the deterioration of fired bodies showed that it is the alkali present that is mainly responsible for the rehydration and expansion of kaolins fired to 1,100° C.

Considerable effort has been given to devising accelerated laboratory tests to produce the long-term effects of natural exposure of tiles.

(*b*) *Clay Technology.*—(i) *Industrial Potentialities of Clay Materials.*—Thirty-five clays and shales from various parts of Australia have been examined in the pilot plant during the past year and recommendations made concerning their suitability for bricks, tiles, pipes, &c. Conjointly with these tests, studies are being made of the mineralogical constitution, particle size, and other properties of the clays to find out if correlations are possible between their basic properties and practical behaviour.

(ii) *Plant Equipment.*—In view of the desire of the structural clay products industry to improve the efficiency of its kilns the Division has continued to give attention to improving existing kilns and to the use of oil for firing them.

Co-operation with the New South Wales State Brickworks in the design of a more economical type of down-draught kiln, embracing automatic stoking and lightweight construction, has continued. Following the 50 per cent. saving in fuel consumption with the first trial kiln, further improvements, including a promising lightweight insulating firebrick produced in the laboratory, are under consideration.

Lubricants, especially oil and to a lesser extent water, used in extruding and moulding clay products, frequently cause serious difficulties in drying and sometimes in the burning of the ware. Trials with a resilient, water-repellent rubber lining of the extrusion die showed that the need for lubricants was eliminated. During tests under commercial conditions, 250,000 bricks were produced satisfactorily before relining of the die was needed.

7. BITUMINOUS ROOFING.

(Division of Building Research.)

(*a*) *Properties of Roofing Bitumens.*—Further studies were made of the rheological properties of two bitumens widely used for roofing work. The results showed that at a shear stress of the same order as that in a natural exposure slump test, and at 65° C., the shear strain of the bitumen with the higher softening point is greater than that of the bitumen with the lower softening point. This explains why the natural exposure slump tests carried out at the Division have shown that, at surface temperatures of 65° C. or higher, the slump of a membrane made with bitumen having the higher softening point was unexpectedly greater than that made with the lower softening point bitumen.

In earlier work on fluxing of bitumens with mineral oil it was found that bitumens of very low temperature susceptibility could be made by fluxing the hardest air-blown bitumen available in Australia with a naphthenic-type mineral oil of high initial boiling point. This work has been extended with a view to the production of a roofing bitumen which is serviceable over a wider range of temperatures than those available commercially. An examination of the properties of the fluxed bitumens produced in this way showed that the one most satisfactory for roofing bitumen work contained 70 per cent. of the original bitumen and had a softening point of 86° C. and a penetration of 75, compared with 141° C. and eight respectively for bitumen from which it was made.

(*b*) *Properties of Roofing Felts.*—To provide data for an analysis of the stress-strain relationships existing in bituminous roof membrances under various conditions, a detailed study was made of the rheological properties of a saturated asbestos felt, a saturated paper felt, and a number of Australian-made raw paper felts. The results illustrated the higher stresses and elongations that can be withstood by paper felts as compared with asbestos felts. The presence of a saturating bitumen adds considerably to both the breaking stress and elongation at failure of the two types of felt, and the stress-strain curve in these cases does not show a sudden break at maximum stress, but rather a gradual decrease in stress for considerable increases in elongation.

The effect of wetting of the saturated paper and asbestos felts on their load-elongation relationships was examined, and it was found that although the breaking load of the wet paper felt was only one-third of that of the dry felt the elongation at failure was almost double. For the asbestos felt the breaking load was less than half of that of the dry felt, but the elongation at failure increased more than fourfold.

(*c*) *Aluminium Foil for Flat Roof Surfacing.*—Aluminium foil is becoming widely used as a heat-reflective membrane for flat roofs, but several difficulties are associated with its use, namely, creep, buckling, and corrosion. To examine the influence of various factors on the buckling, such as length and thickness of aluminium foil and spot versus solid sticking, an experimental membrane was laid at the Division.

Examination of several foil roofs for evidence of corrosion showed that where water was retained for prolonged periods after rain, e.g., in large depressions several feet in diameter in the membrane, pitting corrosion sometimes pierced 0.004 inch of foil. A large amount of dirt retention was associated with such corrosion, and this is believed to be due to differential aeration, the water films between the dust particles and the aluminium being less aerated than the bulk of the water. However, such failures have not been observed with correctly designed roof decks having falls of at least 1 inch in 5 feet.

(*d*) *Asbestos-cement Tiles as Surface Finish.*—A small promenade deck has been covered with asbestos-cement tiles of various makes, sizes, and thicknesses over a conventional bituminous-coated felt membrane. This experimental roof is being used to determine whether asbestos-cement tiles will give a satisfactory traffic-bearing reflective finish for a built-up bituminous membrane roof, and if so, what size and thickness of tiles should be used.

From the performance of this deck to date it appears that a satisfactory surfacing treatment for a promenade deck is obtained by using 12 by 12 by $\frac{3}{8}$ inch asbestos-cement tiles.

(*e*) *Field Trials.*—To further the study of laying techniques and the behaviour of membranes, several experimental membranes have been applied to buildings in the grounds of the Division and to a small concrete roof deck on a residence in a Melbourne suburb. The opportunity is being taken to investigate the permanent shrinkage observed in paper felt bituminous roofings. This shrinkage becomes very large, of the order of 5-10 per cent., once the coating bitumen has been denuded from the felt. It is believed that the phenomenon is due to restraint to swelling when the felt is wet and the bitumen adhesive cold, and freedom to shrink when the felt is dry and the bitumen adhesive warm and less viscous.

8. CONCRETE FLOORS.

(Division of Building Research.)

To compare the effects of concrete and timber floors on the thermal conditions in houses during the winter, temperature measurements were made in a pair of timber buildings erected in the grounds of the Division. These buildings were identical except that one had a conventional timber floor whereas the other had a concrete floor laid on the ground. The conditions of heating, ventilation, and insulation were varied and the results recorded. From these it appears that the difference in thermal performance between the two is comparatively small, the building with the concrete floor having some thermal advantage in the morning and when the outside temperature falls.

Another aspect of concrete floors which has been receiving attention is that of finding suitable low-cost coverings for them. One material that showed considerable promise was gasket cork $\frac{3}{32}$ inch thick. Pilot tests on this material which is available fairly cheaply in long rolls 3 feet wide proved so successful that experimental floor coverings have been laid in a variety of homes and offices to gain wider experience of this material. So far all installations are behaving satisfactorily, except one for which the initial sealing and subsequent maintenance by waxing were inadequate.

9. THERMAL INVESTIGATIONS.

(Division of Building Research.)

(*a*) *Winter Heating.*—In the preceding Annual Report reference was made to the calculation of the hours of heating likely to be needed in the various Australian capital cities. The amount of heating was related to the external weather conditions and the heating to be expected in Australian capital cities calculated on the assumption that the pattern found in the survey was representative. However, as heating requirements may vary with climate it was considered desirable to check the acceptability of the calculations for a more extreme case and so a survey over six weeks was made of the heating needs in Brisbane. Although there was some variation it appears that the results obtained in the Melbourne survey can be applied to the Brisbane area.

(*b*) *Foot Comfort.*—A few years ago an investigation was made into the relation between the environmental temperature, the temperature of a person's feet while sitting, and subjective comfort. From this it was concluded that the floor surface had little effect on the relation between the foot temperature and the environmental temperature and that, in most cases, it had no effect on the correlation of foot temperature and comfort.

However, this study did not differentiate between the temperatures at various heights from the floor and, since a temperature gradient commonly exists in heated rooms, this aspect of the problem was examined experimentally. For the majority of subjects used in the test it was apparent that the air temperature near the floor had the most important effect on foot comfort.

(*c*) *Reflective Insulation.*—Aluminium foil is becoming more widely used for insulating purposes, but there is little information on the effect of dust on the efficiency of the foil in reducing transfer of heat.

Despite statements from overseas that dust layers visible to the naked eye do not seriously affect the emissivity, tests made at the Division showed that an upward-facing reflective surface in a roof space in Melbourne would probably collect sufficient dust in a year to render it ineffective. Reflective insulation should therefore be installed so that a reflecting side faces downward.

10. ARCHITECTURAL ACOUSTICS.

(Division of Building Research.)

The work on architectural acoustics has continued with the investigation of the reverberation times of several concert halls in Victoria and with preliminary measurements of the acoustic conditions in a one-tenth scale model of the new Wilson Hall at the University of Melbourne.

The reverberation times of concert halls have been measured from short bursts of noise with the hall empty and from recordings of symphony concerts with the hall full. The response of the halls to very short pulses of pure tones has also been measured. This information is being compared with subjective assessments by various officers who have attended concerts in the same halls and who have been seated in different parts of the halls for the two parts of a concert. An interesting effect noted already is that the change in reverberation time between empty and full hall corresponds to an absorption per person of audience of only about 1 square foot unit (Sabin), whereas it is generally assumed to be about four units.

The Wilson Hall model has required the expenditure of considerable effort on the development of measuring equipment and techniques, because measurements in uch models depend on facilities for determining acoustic parameters at frequencies higher than those for which tandard equipment is designed.

For acoustic filter and electrical transmission line design, charts and simple formalae can be found which connect the input and output signals for cases where the losses in the filter or the line are negligible. However, when there are losses of energy in the system the difficulty of calculation is greatly increased. A phase theorem to permit the treatment of such cases has been developed.

Assistance was given to the Melbourne City Council in the design of acoustic treatment to reduce the noise level in the Degraves-street subway, and to a musical society for a sound shell on the stage of the Melbourne Town Hall to improve the presentation of chamber music recitals.

XVI. WOOL TEXTILES.

1. General.

An extensive programme of research has been undertaken with the aim of improving the use of wool as a textile fibre. This work is complementary to research in sheep husbandry, described in Chapters V., VI., and VII., which is aimed at increasing the quality and production of wool. The major aims of wool textile research are: (i) to increase the knowledge and understanding of the complex structure of the wool fibre and its physical and chemical properties; (ii) to use this knowledge to improve wool as a textile fibre, to improve technology in wool processing, and to utilize by-products more fully; (iii) to improve machinery used in wool textile manufacture. In these ways it is hoped to preserve wool's unique position amongst the world's textile fibres.

The Organization's work in this field has been distributed among three Wool Textile Research Laboratories, as follows:—

(i) The Melbourne Laboratory at Parkville is responsible for research on the structure and chemical reactivity of wool, on carbonizing, and on certain aspects of felting.

(ii) The Geelong Laboratory at Belmont is responsible for technological investigations.

(iii) The Sydney Laboratory at Ryde carries out research on the physics of wool and the physical and engineering aspects of wool processing.

The Division of Industrial Chemistry has continued a study of the constituents of wool wax and possible ways of utilizing them or their derivatives (*see* Section 4 of this Chapter). It is also studying the structure of proteins in relation to wool (*see* Section 10 of this Chapter). The Division of Entomology is continuing to study the digestive processes of wool-eating insects and larvae (*see* Chapter IX., Section 2).

Wool Textile Research Laboratories.—The outstanding event of the year has been the International Wool Textile Research Conference which was held in Sydney, Geelong, and Melbourne between 22nd August and 9th September, 1955, under the auspices of the C.S.I.R.O., the Australian Wool Bureau, and the Commonwealth Wool Adviser.

This Conference represents the first international meeting of scientists engaged in research on wool textiles and related fields of science, and it is fitting that Australia should have taken the initiative in organizing a conference on a subject which holds such vital importance for her economy. Only by co-ordinating the efforts of the various establishments throughout the world can the wool interests hope to match the immense scientific effort being devoted to the improvement of some of the other textile fibres.

The Officer-in-charge of the Geelong laboratory has visited wool textile mills in the United Kingdom, the United States of America, Italy, France, Belgium, and Germany to see the Australian clip being processed by the main purchasing countries and to ascertain which operations are most urgently in need of technical improvement. An officer who held a Fellowship, supported by the Australian Associated Woollen and Worsted Manufacturers, has now returned to Australia to undertake a study of the mechanical properties of assemblies of fibres, particularly yarns and cloths. Another senior officer, who specialized for many years in the physical properties of raw wool, went abroad to study matters relating to the early stages of wool processing, particularly sorting and drying. Two officers have gone to United States universities following the award of research fellowships to work for twelve months on topics closely related to the research projects they were studying in Australia. One member of staff resigned in order to accept appointment to the Chair of the newly formed School of Textile Technology of the New South Wales University of Technology.

" Wool Textile News " has continued to be well received and in response to numerous requests it is now being forwarded to overseas centres.

Co-operation in research has continued with the New South Wales University of Technology, officers being stationed in the Schools of Applied Chemistry and Applied Physics, and a joint project has been undertaken on the strain and configuration of fibres during woollen and worsted processing with the School of Textile Technology. Close contact has also been maintained with the University of Melbourne Department of Biochemistry and with the Gordon Institute Textile College at Geelong. Instruction in peptide synthesis and accommodation were provided for one of the university research workers.

The provision of textile machinery at the Geelong Laboratory has enabled large-scale experiments, particularly on worsted processing, to receive far more attention than has been possible in previous years. At the Melbourne Laboratory a systematic study has been initiated of the chemistry of the side chains in wool, and where tests show that significant changes have been produced in the solubility properties and biological resistance, samples are subjected to more elaborate testing, for example, to determine moth resistance and shrinkage resistance.

Accommodation and facilities were provided at the Sydney Laboratory late in 1955 for a three-day meeting arranged by the Organization at the request of the Australian Woolgrowers' Council. The purpose of the meeting was to enable representatives of the pastoral industry to learn about the research being carried out in C.S.I.R.O. to improve the efficiency of wool production and utilization. Summaries of wool textile research were prepared and presented at the meeting, and visits to each of the laboratories were made by graziers representing various State and Federal associations.

2. Raw Wool.

(Wool Textile Research Laboratories.)

(*a*) *The Composition and Quality of Wool.*—Through co-operation with the Division of Animal Health wool samples have been obtained from different Merino sheep and from different areas of the same sheep for studies of variation in the amino acid composition. These have shown remarkable uniformity in the composition of wool from the same animal but significant differences between different animals.

In other co-operative studies using wool provided from the C.S.I.R.O. strain trial experiments the significant factors in some aspects of wool valuing have been examined. More reliable information has been obtained than was previously available on how to allow for "handle" when judging fibre diameter, how the crimp varies with diameter in sheep of different strains and environments, and what types of errors in yield sampling might be made by wool buyers.

(*b*) *Branding Fluids.*—"SI-RO-MARK" branding fluid was extensively used in Australia during the year, over 130,000 gallons being produced by various manufacturers. In general the field results with this fluid have been satisfactory and the few difficulties reported by graziers have been investigated.

One outstanding feature of the "SI-RO-MARK" brand is its ease of removal in the normal soap-soda scouring process, and complaints by scourers about difficulties in removing brands have become rare as stocks of older branding fluids are progressively replaced with this new product. The importance to the Australian wool industry of the adoption of a brand for all sheep that can be completely scoured can scarcely be overemphasized.

(*c*) *Fellmongering.*—Further requests have been received for details of the method of recovering wool from sheepskin pieces by heat shrinkage in water followed by vigorous aeration at 40° C. in the presence of calcium to digest the skin tissues. Heat shrinkage is now used in nearly all Australian fellmongeries and it is growing in popularity in the United Kingdom and in New Zealand, but in most fellmongeries there is room for an improvement in the efficiency of aeration.

It is interesting to trace the main developments since the parent process involving heat shrinkage of sheepskin followed by papain or mould enzyme digestion was announced by C.S.I.R.O. in 1945. In 1951, an English firm developed a cheap bacterial protease for use in place of those originally recommended from these laboratories. In 1952, it was shown that vigorous aeration in the presence of calcium digested untreated or sweated sheepskin pieces more rapidly than enzyme, but the latter was still recommended for painted pieces. Meanwhile a machine capable of pulling the wool out of shrunken skin pieces was developed in New Zealand, but since it leaves a high proportion of skin fragments in the wool its application is limited. The success of the aerated bacterial digestion method has been so convincingly demonstrated in Australia that with increasing labour costs it is now becoming widely adopted, not only for treating skin pieces, but also for recovering wool from entire Merino skins. The ribby marks and thinness of most Merino pelts make them less satisfactory for leather manufacture than those from plainer-bodied sheep.

(*d*) *Solvent Degreasing.*—The pilot plant for the jet solvent degreasing process has been run on a continuous basis for a period of three months in an attempt to detect any difficulties which may arise in its full-scale commercial operation. Approximately 80,000 lb. of greasy wool has been used, and the product has consistently shown improved yield and colour of top in comparison with the soap-soda scoured product.

A full-scale commercial plant using this method will shortly come into operation in Australia, and arrangements are being made for the construction of another plant in England for demonstration to the wool textile industry, particularly in the Bradford area. It will be used for degreasing submitted samples of fleece which will then be returned to the mills for assessment of yield of top and noil, appearance, and general behaviour in subsequent processing.

(*e*) *Burr in Wool.*—A survey is being made of the extent to which vegetable matter has increased in the Australian clip in recent years. An attempt is being made to correlate the changes which have been noted in the burr content of wool from certain districts with such factors as pasture improvement and the spread of myxomatosis. Rugging trials have also been commenced in some districts to ascertain whether the improved quality of wool due to protection against burr contamination and weathering is sufficient to offset the cost of the rugs. The rugs are put on the sheep immediately after shearing.

While protection of the fleece against burr contamination must be regarded as an important goal in sheep husbandry, much of the wool grown in Australia at present contains vegetable matter, and the search for chemical agents which promote the action of sulphuric acid on burrs or protect the wool during the carbonizing process is therefore being vigorously pursued. Already these studies have led to the observation that certain detergents protect wool against sulphuric acid damage. This protective effect is not apparent when wool is heated for long periods in dilute solutions of the acid, but it is readily observed if the acid is concentrated on the wool by evaporation as in the commercial carbonizing process. Under these conditions the loss in strength, which is easily detected by hand in wool carbonized with acid alone, is prevented by the addition of detergent to the acid. A non-ionic detergent is preferred for the purpose since less of this is removed from the acid bath with the wool than with anionic or cationic detergents. The improved process is now being tested on an industrial scale.

It is significant that this method of protecting wool against sulphuric acid damage arose from an observation on the effect of certain detergents in preventing disordering of the wool proteins by alkaline solutions, as measured by a change in their digestibility with trypsin.

3. FLEECE BY-PRODUCTS.

(Wool Textile Research Laboratories.)

(*a*) *Wool Wax.*—Research on the flotation method of lanolin recovery from soap-soda scour liquors is being continued with the object of increasing the recovery under industrial conditions.

(*b*) *Potash.*—A survey of the amount of potash present in a wide range of greasy wools has now been completed. It has been found that the mean potassium content is 1.5 per cent., representing approximately 8,000 tons annually in the Australian clip. So far no economical method of recovering this valuable constituent from the greasy wool is in sight.

4. DERIVATIVES FROM WOOL WAX AND SUINT.

(Division of Industrial Chemistry.)

With the completion of work on the aliphatic alcohols of wool wax, attention has been turned to the constituent acids. These acids have generally been regarded as the least valuable of the components of the wax, but if it is to be fully utilized it is essential to look carefully into all possibilities of turning the acids into useful materials. Work has therefore been begun on the preparation of various esters from the wool-wax acids in order to see whether they can be used as plasticizers, large quantities of which are used in the plastics industry. Initially, ways of separating the hydroxy-acids from the other acids are being studied, since it is desirable to examine the behaviour of the individual types of esters, whether or not it may prove feasible or desirable to separate them for industrial use.

The investigation of the acids present in suint has been continued, particular attention being paid to the water-soluble acids. Separation on ion-exchange columns followed by paper chromatography has shown that the mixture is complex; three of the major constituents have been isolated and identified. Gas chromatography is being vestigated to provide a more powerful tool for the com- lete resolution of the acids, both fatty and water-soluble. is hoped that the speed of this method will make possible e investigation of samples from a wide range of wools.

The search for active hormone analogues based on the nosterol of wool wax continues. A progesterone alogue has been prepared and shown to have proges- tional activity. Such activity is unique for a compound aving a saturated ring system, and it may be that a ew type of hormone structure has been found. To erify this a similar analogue of one of the adrenal ortical hormones is being prepared.

Configurations have been assigned to the epimeric methylcholestan-3-ols derived from cholesterol, and ructures allotted to 3-methylcholestenes previously pre- ared by other workers.

5. Wool Textile Processes.

(Wool Textile Research Laboratories.)

(*a*) *Yarn Manufacture.*—Further application has been ade of the radio tracer technique in which individual ores are removed from the wool at an early stage in orsted yarn manufacture, impregnated with a radio- tive compound, and returned to the main bulk. By cating these radioactive fibres at later stages in pro- ssing with the Geiger counter, and determining their ape by pressing the mass of wool against a photo- aphic plate, the amount of residual crimp has been termined in two types of wool differing only in the mber of crimps per inch. Attention is now being ven to the crimp changes and strains in wool pro- ssed on modern machinery such as the "Raper Auto- veller" and the "Ambler Superdraft".

Longitudinal and torsional stresses in worsted yarns various times after spinning are being investigated in attempt to relate the relaxation of these stresses to e relaxation of single fibres and the way in which they e arranged in the yarn. The data may be of imme- ate technological value in such problems as the aging" and "snarling" of yarns.

As part of a study of the irregularities of woollen and orsted yarns a new type of yarn evenness tester is ing developed which appears to be more accurate and eaper than existing types. In an attempt to reduce e irregularity imposed in a drafting system, measure- ent of sliver thickness at the front roller nip is being ed in a servo system to control the draft.

With the development of the solvent degreasing of ool on a pilot-plant scale studies have been commenced the processing properties of the product. This may ad to modification of the conventional treatment which as evolved for soap-soda scoured wool.

In a programme of investigations on the role of lubri- nts in wool processing, a sliver drafting apparatus has en constructed for use in assessing the properties of orsted lubricants, such as olive oil, modified mineral oil, d certain organic compounds. The results obtained ill be compared with those from combing trials in which milar lubricants are used. Conventional lubricants such olive oil do not appreciably affect the friction between rns and metal, but paraffin wax at 0.1 per cent. concen- ation in the yarn is particularly effective, the reduction friction depending on the melting range of the wax d the prevailing temperature. Experiments have also en commenced to compare the various conventional bricants used as batching oils in woollen carding and to evise improved and cheaper products.

(*b*) *Felting.*—The shortage of rabbit fur for felt hat anufacture resulting from the successful spread of yxomatosis in Australia was responsible for an approach eing made to C.S.I.R.O. for assistance in the use of lternative fibres. The histological resemblance of fur rom certain Australian marsupials such as the kangaroo, allaby, and opossum suggested that they would be possible substitutes and this has been borne out by laboratory felting trials. The products, however, are slightly harsher than rabbit felt owing to the larger fibre diameter, and moreover the supply of these fibres may not be reliable. Modification of wool to improve its suitability for hat felts and the selection of appropriate types of wool are also therefore receiving attention.

(*c*) *Dyeing.*—In order to obtain a better insight into the nature of dye uptake by wool, a study is being made of the rate and extent of combination of typical anionic, cationic, and non-ionic detergents with the fibre. An automatic surface balance has also been set up to follow the combination of dyes and other compounds with films of various wool proteins spread at the air-water interface.

In studies of the washing fastness of dyestuffs it has been shown that, when applied in the presence of sufficient acid to reduce the pH of the dye bath to 2, the dye is not as fast to washing as when applied from a bath at pH 4. Loss of dye affinity at the lower pH value is probably due to slight damage of the wool itself, causing it to become more acid and therefore less attractive to the dye anions.

With growing interest in the melange printing of wool tops, attempts are being made to reduce the time of steaming for colour development and to minimize wool fibre damage. By adjusting the pH of the treated fibres to a value below 7 the damage during steaming has been reduced.

6. Modification of Wool.

(Wool Textile Research Laboratories.)

(*a*) *Shrinkproofing.*—A physical investigation of the way in which resins prevent felting shrinkage has shown that they may either stick wool fibres together, roughen the fibres considerably, or mask the scales. These observations should assist the further development of shrinkproofing processes. Proteins are being examined as a cheaper alternative to synthetic resins for shrinkproofing, and a continuous method of treating woven fabrics with casein has been evolved. This process has been simplified to reduce operational costs but it is likely to have only limited application.

Further investigations on the alcoholic alkali method of shrinkproofing are concerned with its application to tops in a continuous process.

(*b*) *Mothproofing.*—Research on the use of dieldrin for mothproofing has shown that concentrations as low as 0.0005 per cent. will protect against moth attack and 0.005 per cent. against carpet beetles. Industrial trials have shown that 0.05 per cent. dieldrin can be readily applied to wool in the last wet process, for example, in the dyeing, bleaching, or milling operations. This particular insecticide is recommended for treating goods which will not be washed frequently. It is fast to dry-cleaning, and will withstand atmospheric exposure. It should not cost more than ½d. per lb. of wool treated.

In studies of the mechanism of digestion of wool fibres by clothes moth larvae it has been shown that the intestines of these larvae contain very few bacteria, and it is therefore extremely unlikely that bacteria play any part in helping the larvae to digest the wool. Thus compounds which merely kill bacteria would not be expected to protect wool against moth attack.

(*c*) *Permanent Pleating.*—A study is being made of the chemical mechanism of permanent set with a view to finding a satisfactory method of permanently pleating all-wool fabrics.

(*d*) *Assessment of Wool Damage.*—In studying existing wool textile processes and in developing new processes, especially those involving wet treatments, it is desirable to be able to detect wool damage. Many methods have been developed for this purpose but they differ markedly in their assessments, and it is often difficult to interpret the results obtained in terms of changes in fibre structure or impaired performance in subsequent processing or use. In order to gain a better understanding of the significance of some of the existing damage tests, and to compare these with some new tests based on precise methods of wool analysis developed in the laboratories, a new programme of investigations has been commenced. In this programme several processing treatments are being applied to wool under normal and severe conditions, and the products will be subjected not only to the conventional damage tests including tensile strength, abrasion resistance, and alkali solubility, but also to others based on the estimation of cystine and cysteine content, amide nitrogen content, thioglycollate solubility, trypsin digestibility, and peptide bond hydrolysis.

7. PHYSICS OF WOOL AND FIBRE ASSEMBLIES.

(Wool Textile Research Laboratories.)

(*a*) *Mechanical Properties of Single Wool Fibres.*—An extensive programme has been undertaken on the mechanical properties of wool. The aims are to understand these properties in terms of the structure of wool and to obtain data of immediate technological value. The mechanical properties of fibres are of outstanding importance in determining their behaviour during processing and their subsequent performance in clothing. If these properties can be properly explained possibilities will appear for modifying them in ways which will improve the competitive position of wool.

If a wet or partly wet wool fibre is extended at a steady rate, the tension in the fibre will increase rapidly until about 5 per cent. extension, then slowly until about 30 per cent. extension, and then rapidly until the fibre finally breaks. If the extension does not exceed 30 per cent., the fibre, after a waiting time, can be made to repeat the process. The precise values for extension and tension depend in a complicated way on how fast the test is performed, how much water the fibre has absorbed, the temperature, and what tests have been made previously on it. The research consists in determining these relationships and building up theories to describe and explain them.

There are other test conditions such as observing the extension of a fibre under constant tension, known as a creep test, or observing the change in tension under constant fixed extension, known as a relaxation test. These have been used in the Sydney Laboratory to examine in detail the creep and relaxation of wool in the range of extensions 0-30 per cent., for dry and wet fibres, and for a range of temperatures. So far a theory has been worked out which describes the behaviour adequately for wet fibres in the range 5-30 per cent., and it is being extended in an attempt to cover other cases.

Changes in the X-ray diffraction pattern of wool occur during mechanical extension. Those are also being studied to throw light on the process. The dielectric properties are also being studied to provide some information on how water is held by wool and why water changes the mechanical properties of wool.

(*b*) *Regain of Wool.*—Research into the way wool and water combine has continued because of the commercial and scientific value of such information.

The regain (amount of water divided by the dry weight) of several samples of wool has been measured accurately over a range of relative humidities, and particular attention has been given to the problem of determining " true dry weight ". This latter measurement is of particular importance in the testing of wool samples for buying and selling.

Another way in which water is absorbed or lost to the air by wool fibres is also being measured by means of a specially developed apparatus which follows weight changes in a single wool fibre. The fibre is kept in transverse vibration under constant tension, at its resonant frequency. This frequency provides a measure of the weight of the fibre. It changes with water content. The apparatus is extremely sensitive, and changes of one part in 1,000 in the weight of a single fibre can be readily seen. It has made possible the discovery of new facts about water sorption. Two stages have been found in the process of absorption of water vapour. When a fibre, which has been allowed to come to equilibrium in an atmosphere at one particular relative humidity, is moved to an atmosphere at a higher relative humidity, it absorbs water vapour rapidly at first for times of the order of seconds to a few minutes. Then quite a large proportion of the total water is absorbed in a second stage which takes many hours. However, it has also been found that if the change in relative humidity is sufficiently large the second stage is eliminated. On the other hand, when a fibre is losing water the two similar stages still exist, but the second stage cannot be eliminated by making a big change in the relative humidity of the atmosphere. These findings may in due course affect methods used in drying and wetting the wool in manufacture and testing.

Another investigation concerns the rate of swelling of wool fibres when liquid water is taken up under various conditions of temperature and effective relative humidity. This provides useful information on the physical structure of wool and is highly relevant to the dyeing process.

(*c*) *Friction.*—A study is being made of the laws of friction for a fibre rubbing on a surface. An interferometric method has been developed for measuring the area of contact between a fibre and a glass plate. These areas are extremely small but are important in determining the forces required to move fibres past other surfaces or fibres which they touch.

8. HISTOLOGY OF WOOL FIBRES.

(Wool Textile Research Laboratories.)

Methylene blue staining and examination under the microscope have shown that mohair and a sample of crimpless Merino wool resemble Lincoln wool in that the more highly stained ortho (S) cells are located in the centre of these fibres leaving a ring of para (H) cells distributed around the periphery. This gives further support to the view that crimp in wool is associated with the bilateral structure, that is with the grouping of the ortho and para cells on opposite sides of the fibre. Where this arrangement is absent the fibre lacks crimp.

9. WOOL PROTEIN CHEMISTRY.

(Wool Textile Research Laboratories.)

(*a*) *Preparation and Properties of Extractable Wool Proteins.*—Many of the methods which have been evolved for studying the structure and chemistry of proteins are applicable only to proteins in solution. The thioglycollate fractional extraction method of preparing a soluble protein fraction which moves as a single component on electrophoresis is therefore of considerable importance and is being widely used. Re-formation of the disulphide bonds which are split in the process of preparation was formerly prevented by blocking the sulphydryl groups with iodoacetamide. A wide range of other compounds has now been shown to be equally effective, including various organic mercury derivatives. Iodoacetic acid has given the most soluble derivative and this product has been used in a wide range of physico-chemical studies. Its molecular weight has been determined by ultracentrifugation in conjunction with viscosity and diffusion measurements, and shown to approximate 2,000,000 in aqueous solution. However, it dissociates into units of about 50,000 molecular weight in the presence of urea or of the wetting agent sodium dodecyl sulphate. Soluble proteins prepared from wool by the peracetic acid-ammonia extraction method gave molecular weight values of similar magnitude to those observed for the thioglycollate-extractable protein.

(*b*) *Amino Acid Composition.*—It is becoming more pparent that the rapid amino acid analysis of different ools and of the proteins and peptides derived therefrom ill provide an essential foundation for the elucidation f the molecular structure of wool and its chemistry. ignificant differences have been observed in the amino cid composition of three of the six extracts obtained y fractionally extracting wool with alkaline thioglyollate, and these represent the most convincing evidence et obtained of the protein heterogeneity of the fibre.

(*c*) *Studies with Model Compounds.*—Peptides similar o those which can be derived from wool by partial ecomposition are being synthesized in the laboratory o serve as model compounds for the study of wool hemistry. Work is being concentrated on cystine pepdes, in view of distinctive properties conferred on wool y this particular amino acid, and the preparation of a eptide containing two units of cysteine separated by four ther amino acid units has now been completed. This roduct can be readily oxidized to the ring form and educed again just as with the wool itself, and much aluable data are expected to be derived from investigaon of its properties.

Another model compound has been prepared merely y covering the sulphur-containing group of cysteine ith a basic group and then linking together many units f this product. Modification of the sulphur-containing roups has been found to make this polymer susceptible o attack by the enzyme trypsin. Similar modification f the cysteine in wool should enable trypsin to attack it lso, to provide useful fragments for wool structure udies.

The protein insulin, like wool, contains a high proortion of cystine, and moreover its precise amino acid omposition is known. It therefore serves as an dmirable experimental model which embodies some of he chemical features of the simple cystine peptides and n addition properties which are associated only with arge molecules containing cross-linked peptide chains. areful study of the structure of insulin has suggested hat the helix in which the amino acid units are believed o be arranged in proteins may reverse direction at certain oints. The same type of structure would be expected o occur in some of the cystine-containing proteins of vool.

(*d*) *Infra-red Spectroscopy.*—By treating wool with eavy water, known chemically as deuterium oxide, a hange in the infra-red absorption spectrum of the fibre as been obtained which indicates that this substance is nable to penetrate into certain regions. These are elieved to be the crystalline regions of the fibre. The reatment also causes the hydrogen atoms in all the amide roups of wool to be replaced; this indicates that they are robably not distributed uniformly through the fibre but re restricted mainly to the non-crystalline regions.

10. PROTEIN STRUCTURE.

(Division of Industrial Chemistry.)

Fundamental to the investigations on protein structure s the synthesis of crystallizable peptides for X-ray xamination. A compound containing the amino acid equence proline-hydroxyproline, believed to be important n collagen, has been prepared, and preliminary X-ray ata have been recorded to assess its suitability for full nalysis. The alkaline degradation of derivatives of oluene-*p*-sulphonyl-α-amino acids mentioned in the last Report has been further studied, and the factors influencng the extent of the degradation have been established, o that conditions can be found for obtaining maximum ields in the synthesis of toluene-*p*-sulphonyl peptides.

X-ray studies of the amino acids, from which peptides nd proteins are built up, have continued. In the crystal tructure analysis of aspartic acid hydrochloride, a more laborate formulation of the structure factor equation has been required to take into account the thermal vibrations of the individual atoms. Further refinement of this structure is being made. Earlier experience with the "heavy-atom" technique in the analysis of the structure of large molecules and with full or partial three dimensional data, has indicated that these methods are suitable for the attack on peptides of structural significance, provided that suitable derivatives can be obtained. The computing machines being built in the Division will be necessary for the full exploitation of these techniques.

11. BIOLOGICAL DEGRADATION OF TEXTILES.

(Wool Textile Research Laboratories.)

(*a*) *Wool Damage by Bacteria.*—When wool is sterilized by the usual method of heating with steam under pressure in an autoclave, its proteins are severely damaged, as has been demonstrated by measuring its reduced alkaline thioglycollate solubility and enhanced digestibility in trypsin. Many published reports on the bacterial damage of wool sterilized in this way are therefore unreliable. A new method of sterilizing wool without the application of heat has been devised, and therefore the accurate assessment of the action of pure strains of bacteria on undamaged wool has now become possible.

(*b*) *Fungal Degradation of Cellulose.*—Of the group of enzymes produced by *Stachybotrys atra* and responsible for the breakdown of cellulose, a cellulase has now been prepared in bulk culture and shown to attack compounds ranging from filter paper cellulose down to the three-glucose molecule cellotriose. It is unable to initiate degradation of highly crystalline cotton cellulose. Cellobiase, another important member of the group, continues the degradation by splitting the two-glucose molecules of cellobiase into glucose molecules, and its production in relation to that of cellulase is now being investigated. A β-glucosidase differing from cellobiase is an enzyme of *S. atra* which has received the greatest amount of attention so far. It has been purified and allowed to act on a wide range of glycosides, some of which had not been previously synthesized, and from measurements of the rate of action and of the effects of inhibitors a theory to explain some aspects of its mode of action has been deduced.

12. GENERAL PROTEIN INVESTIGATIONS.

(Wool Textile Research Laboratories.)

Research on collagen has been concerned with the development of methods of incorporating radioactive glycine into this protein and into other proteins of the skin, and with the purification of these labelled products. Studies of the distribution of radioactive glycine within the molecules of collagen and associated skin proteins will enhance our knowledge of their structure and thereby contribute towards their most effective utilization in the manufacture of leather and other products.

XVII. FODDER CONSERVATION AND PLANT FIBRES.

1. GENERAL.

Fodder conservation is essential for the agricultural prosperity of Australia. As part of the annual programme of farm management, fodder should be stored during the spring to meet the exigencies of the following winter; perhaps even more important in many districts is the need to have sufficient fodder on hand to provide at least a subsistence ration for stock in time of drought. Although haymaking and, to a much less extent, ensilage are widely carried out in this country, an even more extensive programme of these types of conservation is called for; at the same time every effort should be made to reduce, by improved techniques, the enormous losses which so often occur.

The Plant Fibre Section of C.S.I.R.O. recently undertook the study of various basic problems associated with haymaking and ensilage; it has also assumed responsibility for research on haymaking machinery previously carried out at the School of Agriculture, University of Melbourne. Considerable interest and tangible support for this work has been received from the Australian Dairy Produce Board and a number of leading agricultural machinery manufacturers. At the same time, the work of the Section on plant fibres has been very much curtailed. Most of this work was commenced during the war to assist with agricultural, processing, manufacturing, and utilization problems of the flax industry. This industry is now being continued on a much reduced scale. Furthermore, interest in other plant fibres such as jute and kenaf has also waned in this country as supplies from overseas have become easy to procure.

2. FODDER CONSERVATION.

(Plant Fibre Section.)

(*a*) *Chemical Investigations.*—Although there are limitations to the use of chemical analyses for assessing fodder value, such analyses provide a very useful guide to the changes accompanying various methods of conservation and storage. The constituents being studied in most detail are those containing nitrogen and also the various sugars.

(*b*) *Physical Investigations.*—Studies to provide basic information on haymaking operations are being made of the drying characteristics of pasture plants, their moisture content equilibria, and the effect of drying conditions on respiratory losses. A mechanical method of separating the fragile from the tougher portions of plants has been developed to measure their susceptibility to mechanical loss.

(*c*) *Microbiological Investigations.*—Detailed studies are being made of the bacteria associated with the ensilage of various crops. In particular the lactic acid bacteria from crops of lucerne, rye grass, and clover have been isolated and characterized. Changes in the nitrogenous constituents of plant material during ensilage are of prime importance and these are also being investigated.

(*d*) *Haymaking Investigations.*—Experiments begun the previous year were continued last summer at the State Research Farm at Werribee and the C.S.I.R.O. Field Station at Cobram. The object of these field trials has been to determine the effects of time and method of raking on the characteristics of the windrows formed, their rate of drying, mechanical losses, and change in chemical composition. Experimental difficulties, mostly associated with sampling, have detracted somewhat from the value of this work and improved techniques are now being sought. Investigations have also been made of the pick-up of moisture by bales of hay exposed to rain and of the characteristics of baler twine.

(*e*) *Ensilage Investigations.*—A number of ensilage trials have been made of rye grass, clover, and lucerne using small laboratory silos. In each case botanically pure material has been used and the temperature maintained at about 38° C. The variables examined have been the maturity of the crop and the compaction pressure. With some trials the effects of additions of molasses and sodium metabisulphite have also been studied.

3. AGRICULTURAL ENGINEERING.

(Plant Fibre Section.)

(*a*) *Side-delivery Rake.*—Following a geometrical analysis of the action of existing hayrakes a new design was proposed which, it was thought, would handle the hay more gently. An experimental unit, based on this design, has been constructed and given a preliminary trial. However, owing to various mechanical troubles and, more especially, to the sampling difficulties associated with haymaking trials in general, no conclusions regarding the rake can yet be drawn.

(*b*) *Mower.*—An investigation of mower design and operation is well under way. The field performance of power take-off mowers provide ample evidence that existing designs are far from satisfactory. Equipment has been set up to enable studies to be made of stubble pattern, the behaviour of the crop in and near the cutting zone, the cyclical energy demand and the cutting force, and the mechanical properties of crops. Various knife shapes and both single and double knives are being investigated.

4. PLANT FIBRE INVESTIGATIONS.

(Plant Fibre Section.)

During the past twelve months, work on fibres has largely been confined to co-operation with the Flax Commission, the Victorian Department of Agriculture, and the Department of Territories in evaluating and spinning fibre from various field trials.

XVIII. INDUSTRIAL CHEMISTRY.

1. GENERAL.

The Division of Industrial Chemistry represents the major concentration of chemical research within the Organization, although much chemical work is undertaken in other Divisions and Sections.

This Division was formed: (*a*) to promote greater technical efficiency in established industries; (*b*) to stimulate the establishment of new industries; (*c*) to encourage the use of raw materials of Australian origin (*d*) to seek substitutes for imported materials; and (*e*) to find uses for by-products not utilized.

In addition to its basic chemical work, the main research activities within the Division deal with mineral utilization, cement, ceramics and refractories, organic chemicals, wool, brown coal, and water conservation.

The Division's study of the constituents of wool wax and possible ways of utilizing them or their derivatives is described in Chapter XVI., Section 4. The Division is also studying the structure of proteins in relation to wool (*see* Chapter XVI., Section 10). The Division's work on the utilization of brown coal is described in Chapter XX., Section 6.

Division of Industrial Chemistry.—Since the formation of the Division in 1940, a major portion of its research programmes has necessarily been devoted to basic studies in various fields of chemistry. These studies were frequently undertaken to provide the background for the solution of a particular practical problem, but an endeavour has always been made to ensure that the manner of tackling the problem would lead to results of general as well as particular value. It is a noteworthy result of this policy that most of the practical successes that have been achieved in recent years are in directions which could not have been foreseen when the original basic work was undertaken, and are of a level of importance far higher than the solution of a particular problem could have been. For example, rather than provide a routine service in spectrographic analysis, a critical study of emission spectroscopy was made which directed attention, in turn, to absorption spectroscopy and led to a new and potent analytical method. Again, a study of methods of separation based on adsorption processes has led to a new chemical engineering development, the "resin-in-pulp" process, which eliminates a costly filtration step in the recovery of uranium from ore pulps and which shows promise of application in the ecovery of gold and in other separation processes. esearch on the physical chemistry of surface films on ater has given a means of reducing the enormous astage of water by natural evaporation. Originally ndertaken in relation to the gasification of brown coal, udies on the technique of fluid-bed roasting have led important advances in copper metallurgy.

These advances have found ready recognition both in ustralia and overseas: the atomic adsorption spectroeter is being prepared for manufacture under licence by ilger and Watts Ltd.; successful pilot-plant developent of the resin-in-pulp process, financed by the Ausalian Atomic Energy Commission and the Rio Tinto ompany, through its Australian associates, Mary athleen Uranium Ltd., has prepared the way for egotiations for licensing the process; the discovery that etyl alcohol can be used to reduce natural evaporation as inspired parallel experiments in Kenya and India, and uring the year, the Southwest Research Institute of an Antonio, Texas, sponsored a visit to America by officer to advise the Institute on the initiation of rther work there. Recently, the copper metallurgy proamme has been extended to include also a study of the ectrowinning of copper recovered from the fluid-bed aster calcine, and the original sponsors, Mt. Lyell ining and Railway Co. Ltd. and Mt. Morgan Ltd., ave been joined by the other major Australian copper oducers, Mt. Isa Mines Ltd., and Peko N.L. Ltd.

Outstanding work by officers of the Division in other elds has been recognized by invitations to attend overas conferences. Dr. A. L. G. Rees attended the Third ternational Meeting on the Reactivity of Solids at adrid; Mr. R. G. Thomas represented the Organization the International Conference on the Peaceful Uses Atomic Energy; in recognition of his work in electron icroscopy, Dr. A. J. Hodge was invited to a conference New York on tissue fine structure, and Mr. B. W. ilson attended, by invitation, the World Symposium on e Utilization of Solar Energy at Tucson, and Phoenix, rizona. These visits have at once provided an oppornity for these officers to contribute to the proceedings the Conferences and have also given them an invaluble opportunity to become acquainted with modern ends in their respective fields.

During the year, Dr. J. D. Morrison was awarded a ommonwealth Fund Fellowship for his work in mass ectroscopy and will study for a year in the United ates of America. Dr. K. M. Alexander has taken up French Technical Co-operation Scholarship and, after months in Paris, will study for twelve months at the anford Research Institute under a Fellowship of that stitute.

In other ways also, officers of the Division continue take their place in international science. The Chief the Division is Convenor of the National Committee r Pure and Applied Chemistry which is affiliated with e I.U.P.A.C. Dr. A. L. G. Rees is also a member of is Committee. Dr. J. M. Cowley has accepted ppointment as the Chief Organizer of the Symposium Electron Diffraction Studies of Solids and Gases at e forthcoming Montreal meeting of the International nion of Crystallography.

Dr. A. McL. Mathieson has been awarded the degree Doctor of Science in the University of Melbourne, in ecognition of his X-ray work on molecular structure. r. M. E. Winfield has been admitted to the degree of octor of Science in the University of Western Ausalia for his work on heterogeneous catalysis.

It has been a pleasure to welcome as a guest worker the Division Dr. Kiang Ai Kim of the University of alaya. Dr. Kiang spent six weeks studying techniques nployed in the separation and purification of natural roducts. As a result of his visit, the Division has been sked to arrange for an Australian scientist to go to Malaya to help establish a phytochemical survey in that country. From within Australia, there have come to the Division for periods up to several months a number of investigators whose aim has been either to collaborate directly on a scientific or technological problem or to learn some technique already established in this laboratory.

The donation of a compressive strength machine by the Adelaide Cement Co. Ltd. is gratefully acknowledged.

The Division's general workshop, which has, since its formation, shared accommodation with the workshop of the Aeronautical Research Laboratory of the Department of Supply, will shortly be moved to a new building.

2. MINERALS UTILIZATION.

(Division of Industrial Chemistry.)

Certain phases of extractive metallurgy continued to form an important part of this work. Projects related to the recovery and purification of uranium, thorium, zirconium, and hafnium derivatives from Australian mineral sources have an obvious relation to current requirements in nuclear energy developments. The continuing importance of the germanium in transistor devices has justified a survey of Australian occurrences of this element and has emphasized the necessity for improvements in processes for extraction of germanium from widespread low-grade sources. In this, as in the case of copper extraction, the advantages which may be expected to accrue from the development of hydrometallurgical extractive processes have been emphasized in the projects concerned. The important influence often exerted on the physical and chemical properties of various industrial materials of mineral origin by small amounts of impurities has formed the basis of very diverse investigations in the Section's programme. Projects based on chemical crystallography, phototropic compounds, electrowinning of copper, and separation of hafnium from zirconium are among those which may be cited in that category. Studies on the properties of new inorganic compounds have been undertaken concurrently with the applied investigations, with the object of extending the industrial utilization of mineral derivatives.

(*a*) *Hydrometallurgy of Copper.*—Work on the acid leaching of copper from calcines produced in the fluosolids roasting of chalcopyrite concentrates from Mount Lyell and Mount Morgan have been continued. Impurities which are dissolved concurrently with the copper include iron and molybdenum, and these two elements have an important bearing on the subsequent electrowinning of copper from the leachate. Research has continued on the methods for the most effective oxidation of ferrous iron prior to its chemical precipitation as hydroxide or its adsorption on ion exchange-resin. Current research has demonstrated for the first time that a pronounced embrittlement in the electrodeposited copper is attributable to small amounts of molybdenum in the electrolyte. This embrittlement can be a limiting factor in the production of starting sheets. This observation has led to a survey of the occurrence and distribution of molybdenum in the ores and subsequent metallurgical products. Methods for the removal of molybdenum from the electrolyte or, alternatively, for eliminating the embrittling effect on the copper produced were devised and have proved successful in laboratory-scale tests.

(*b*) *Uranium Extraction.*—Work has continued on the Division's process, whereby uranium is preferentially leached by sulphuric acid autogenously produced from pyrite either present in, or added to, the ore. In some locations this may well prove to be the cheapest way to provide the sulphuric acid needed. Detailed studies were made on the mechanism of acid generation from the pyrite as a basis for application of the process to other metals. Major improvements were made in the design of the reaction vessel particularly to enable adequate control of agitation and aeration during leaching. Non-pressure leaching tests were conducted on numerous Australian uranium ores, particularly those from the Northern Territory, to determine the respective merits of leaching under acid and alkaline conditions, at constant pH, and under "acid-cure" conditions, &c. Particular attention has been paid to the influence of clay-like minerals on the yield of uranium obtained by acid leaching. The regeneration of nitric acid from barren liquors has also been examined with a view to inexpensive recovery of the acid. Co-operation with the Australian Atomic Energy Commission was continued, especially with regard to the testing of new ores and the examination of special samples from Rum Jungle. Extensive analytical assistance was supplied for the resin-in-pulp project described elsewhere.

(*c*) *Zirconium-hafnium Separation.*—The chemical separation of the small amount of hafnium from the zirconium, with which it is always associated in minerals, is a necessary requirement if the zirconium is to be used for a cladding element for uranium rods in a nuclear reactor. The separation involves considerable chemical difficulties and the method devised in this laboratory has notable advantages compared with processes currently in use overseas. Pound-scale separation of zirconium and hafnium tetrachlorides by preferential reduction of the zirconium to the trivalent state has been developed into a semi-continuous process which has been patented. Either aluminium or zirconium metal has been used to reduce crude zirconium tetrachloride to the involatile tricholoride, and the unreduced hafnium chloride has been sublimed away. The hafnium-free zirconium trichloride has then been disproportionated *in vacuo* to give a sublimate of pure zirconium tetrachloride and a residue of involatile dichloride. This dichloride has then been used to reduce a further batch of crude tetrachloride to the hafnium-free trichloride and the cycle of reduction, sublimation, and disproportionation can be repeated indefinitely using a fresh batch of crude anhydrous chloride for each reduction. A mild steel reaction vessel similar in design to the Kroll reduction vessel has been used for these investigations and has shown no signs of serious corrosion after twelve months' service. A programme of fundamental work has provided data on the reduction of zirconium tetrachloride to the trichloride. This information has made possible the recovery, in a single cycle of reduction and disproportionation, of more than 80 per cent. of the crude zirconium chloride as a product with a hafnium/zirconium ratio of 0.05 per cent. An investigation, which is being conducted jointly with the Metallurgy School of Melbourne University, on the electrolysis of the lower chlorides, has been continued. A study of the behaviour of zirconium carbide electrodes in fused salt baths was also commenced.

(*d*) *Thorium Purification.*—Greatly increased attention has been paid to thorium over the past year because of the fact that the fissionable isotope U^{233} can be made in an atomic reactor from thorium metal or suitable thorium compounds. Purification of thorium, therefore, has acquired a new significance. Since metal of the highest purity is obtainable by thermal decomposition of the iodide, synthesis of the tri- and tetraiodides has been studied and preliminary kinetic studies made of the rate of iodination of crude thorium. It has been established that the carbide reacts with iodine and that there is less tendency to form undesirable lower iodides in this reaction. Thorium oxyiodide has been synthesized by the reaction between tetraiodide and oxide and by the reaction of the tetraiodide with oxygen. Very low yields of tetraiodide may be obtained in iodination reactions if the crude metal contains a notable amount of oxide or oxygen, since the temperatures of iodination and oxyiodide formation are relatively close. A number of very pure thorium filaments have been grown and soft, ductile metal has been obtained. A study of optimum conditions of growth and of impurity transfer was commenced.

(*e*) *Germanium Survey and Extraction.*—The programme of assessing the availability of germanium in Australia has been concluded. It has been established that the major potential source of germanium is flue dust from coal-fired boilers of power generating stations. The germanium content of these dusts varies with the coals used and the quantity of coal ash carried into the flues by several types of combustion units. Dust of highest germanium content located ranges up to 8 oz. of germanium metal per ton, but, in general, the amount is less than this figure. The low concentration of germanium requires the development of new extraction techniques, and preliminary work was done on the richer dusts. Both physical and chemical concentration has been considered. Sizing tests have shown that most of the germanium is found in the finest material. Chemical extraction tests show promise for economical extraction of a substantial portion of the germanium and will be continued.

(*f*) *Lamellar Compounds.*—Following the conclusion of theoretical studies on these compounds attention was directed towards development of useful applications for them. Incorporation, in cured rubber, of the special form of finely divided carbon resulting from thermal decomposition of graphite oxide has been found to confer greatly enhanced electrical conductivity on the product compared with that obtainable with other types of carbon. Graphite oxide carbon also imparts to rubber unusual curing characteristics and hardness.

Fundamental studies of the intercalation of metals in graphite as chlorides have led to the discovery that certain paraffin-soluble, metal-organic compounds are effective as additives for suppressing the smoking of hydrocarbon fuels. Substantial smoke abatement has been noted when these substances are added to fuels used in oil-fired furnaces and in petrol engines.

(*g*) *Phototropic Compounds.*—Earlier work on the light sensitivity of titanium oxide pigment containing small amounts of certain metallic impurities has been extended to include the oxides of aluminium, tin, germanium, and tantalum as host oxides. These have been shown to exhibit phototropic effects when sensitized with small amounts of impurities such as iron, nickel, copper, chromium, and cobalt. The sensitization of the host oxide in these instances is usually more specific than is the case with titanium oxide. By the use of suitable light filters the most effective wave lengths of the incident light for development of phototropic effects in these several compounds were determined. The theoretical aspects of this work are directly related to the technology of inorganic pigment preparation where the presence of impurities is often a limiting factor in the permanence, or constancy, of colour tones.

(*h*) *Transition Group Sulphides, &c.*—Further exploratory work was done on the synthesis of sulphides, selenides, and tellurides of titanium, zirconium, and thorium. Of some fourteen distinct compounds synthesized, ten are new insofar as an examination of their physical characteristics is concerned. Properties such as stability to heat and oxidation, electrical conductivity, and their possible use as dry lubricants have been determined. Valuable data on the progressive transition of physical properties with chemical variation in the binary components of this series have now been obtained.

(*i*) *Chemical Crystallography.*—Studies of crystalline but chemically imperfect solids were continued with a view to obtaining a better understanding of the utilization of minerals. The crystal structure of a lithium vanadium oxide was determined. This material is chemically inert and a good conductor of electricity. A survey was made of other oxides which might be expected to have anomalous properties, and amongst these a ternary oxide of hexavalent chromium and a mixed tungsten-zirconium oxide have received special attention. The incorporation of sodium into the lattice ferric fluoride was experimentally established; this mpound may have a possible use in water purification. non-stoichiometric oxyfluoride of cerium was also idied.

(*j*) *Fluorine Chemistry*.—Since fluorine is being used ore extensively each year in overseas countries, there is ed for Australia to develop in this direction also. A orine cell was constructed in this Division and operated tisfactorily. Techniques have been developed for oiding the hazards associated with the handling of ementary fluorine, bromine trifluoride, and anhydrous drofluoric acid. A variety of reactions involving ceric ioride, its synthesis, and the formation of cerous yfluoride were studied.

3. CEMENT AND CERAMICS.

(Division of Industrial Chemistry.)

Work has continued in two main fields: (*a*) the manucture, properties, and utilization of Portland cement, d (*b*) the investigation of raw materials and processes ed in the Australian ceramic industry. The proamme is designed to provide answers to practical probms of both special and general character, but as these ten require a good deal of fundamental research, prots of a more basic type form an important part of the ork.

Inquiries have come from a number of industries conrned indirectly with materials and processes connected th the fields of cement and ceramics. Several new coerative investigations have been initiated by companies rectly concerned with cement manufacture, clay proiction, whiteware manufacture, and the design of etallurgical refractories. Financial assistance has been ovided by the Cement and Concrete Association of ustralia, and a valued gift of equipment has been made one of the member companies.

(*a*) *Cement Hydration and Strength Development*.—oduction in pure form of some of the compounds esent in cement clinker has given a basis for work on e rates of the reactions involved in setting and hardeng of cement pastes. First determinations on dicalcium icate have shown that the hydration rate is controlled temperature in a manner which suggests that viscosity the water phase exerts a controlling influence on the stem. The other main factor in the reaction rate pears to be linked with the progressive increase in the ickness of gel layers surrounding primary particles of inker materials. The implications of this are being idied, and similar determinations on tricalcium silicate e under way.

(*b*) *Flow Properties of Mortars and Concretes*.—The fects of air-entrainment and the mechanism involved erein have now been studied over a wide range of stems, and results have been published. The project is developed into an extensive investigation of the iysical properties of wet, plastic mortars and concretes. new type of admixture has been discovered which iproves the texture and plasticity of mixtures low in ment and fine aggregate. The addition of small nounts of a complex organic compound to the mixing ater permits production of a soft easily worked concrete, hich may be vibrated into place without bleeding and gregation.

(*c*) *The Cement-aggregate Bond and Crack Develop-ent*.—From the results of an earlier project on the operties of pozzolanic cements, a new approach has en developed in the study of the strength of concretes. rength depends on the properties of the cement paste, e degree of adhesion of the paste to aggregate, and e strength of the rock used as aggregate. The relative iportance of these factors has been demonstrated in a ries of experiments using different types of pastes and gregates, and the results are in course of publication.

The most important features of the new results are. (1) that the strength of the cement-aggregate bond may exceed the strength of the paste matrix in certain concretes; (2) that the surface of any aggregate has more or less "pozzolanic" activity; (3) that the mechanism of failure of concrete under load can depend on the water-cement ratio during mixing; and (4) that moderate amounts of alkali in cement may have a beneficial effect on the early strength of concretes.

On aging and weathering, the strength of concrete is lowered by fine cracking due to shrinkage or expansion. Detailed study of volume changes due to freezing and the action of various salt solutions has shown that the best method of prevention of deterioration should be based on reduction of the permeability of concrete. Surface treatments and additives in the mix have been investigated with this in mind. Some of the additives are giving satisfactory results and will be examined on a larger scale.

(*d*) *Clay and Whiteware Investigations*.—The study of the microstructure or "fabric" of whiteware and clays has continued with special reference to particle orientation and the relation of this to recovery from deformation and to effects such as uneven drying and firing shrinkage. The results have attracted particular attention in the United States of America, where manufacturers and research workers have combined to arrange for a member of the Division to visit plants and laboratories and to discuss the topic.

In a study of the penetration hardness of clays, it was found that the load-bearing capacity of plastic specimens was related to the water content in a critical manner over a narrow range. This may lead to more quantitative evaluation of industrial shaping processes. It also has a bearing on the assessment of conditions causing landslips and rockfalls.

Articles prepared for trade publications have concerned the properties of clays from Queensland, Western Australia, and Victoria, the problems of making craze-free glazes, and alkaline casting slip control. An examination of the behaviour of firing of Cornish stone has been completed and will serve as a standard for evaluating local feldspathic fluxing materials.

The fundamental investigation of the structure of vermiculite, regarded as one of the best developed clay minerals, has yielded information on the mechanism of thermal dehydration of this kind of layer-lattice structure. During this work, visible rehydration of vermiculite was discovered, an effect which may lead to a valuable technique for further investigation of the general clay-water system.

Some of the Victorian clays of current importance in industry have been examined in the field, and small-scale trials of suggested whiteware body compositions have given information of value to the growing local tableware industry.

(*e*) *General Refractories*.—The embrittlement of silica bricks in both carbon monoxide and hydrogen has been linked with the devitrification of the glassy bond, giving at least a partial explanation of the deterioration. Other siliceous refractories are being examined to determine whether any compositions are less susceptible to the effect, which is probably of significance in reducing the life of linings in gas retorts under heavy steaming conditions.

Australian silcrete bricks have shown satisfactory behaviour in a steel furnace trial. The occurrence and petrography of the source materials have been described in publications which also included data on hitherto unexploited Australian quartzites.

Further progress has been made in surveying the physical properties of the general refractory products of Australian industry. The possible uses of local zircon sand as a refractory raw material were investigated. Phase equilibrium studies indicated that certain limited compositions based on zircon would be of practical interest, and trial bricks have been fabricated. The use of hot-pressing as a method of shaping various refractories has been explored and shows some success in the production of high-density products.

An examination of refractory materials from a burnt-out copper melting furnace suggested that accepted industrial practice could be improved by replacement of silica by alumina in the refractories. Data on the phase relations of silicate systems containing copper are being obtained by the current experimental work, whilst industrial trials are proceeding simultaneously.

(*f*) *Special Ceramics and Cermets.*—A project involving the use of organic additives to replace acid in conventional aqueous slip-casting techniques has been successfully developed. In an extension of the project magnesium oxide has been cast from non-aqueous slips with good mould extraction and green strength. Improvements in sintering techniques have produced fired ware of much higher density than typical commercial products.

Thoria and zirconia, moderate electrical conductors at high temperatures, have been studied in relation to the development of composite heating elements for use in air above the normal temperature limits of commercial devices.

Molybdenum disilicide, a synthetic material showing promise for high-temperature mechanical and electrical applications, was made by direct reaction in argon. Attempts are being made to combine synthesis and shaping in one operation using the hot pressing technique. This silicide and metal-bonded titanium carbide are both being examined as potential die materials with which to extend the pressure range of the hot press method.

Other investigations are concerned with the effect of small additions of specific materials to the alumina-chromium system and to the refractory material zirconia. If additives can overcome the wetting problem in the alumina-chromium cermet, it should prove to be an excellent high-temperature engineering material. A reliable additive to suppress the zirconia inversion would also make available a valuable special refractory.

(*g*) *Adelaide Ceramics Laboratory.*—This group has continued as a local advisory and developmental centre in collaboration with the School of Mines and Industries and the Department of Mines. Raw materials and processing problems in the heavy clay industries have formed the main projects. Detailed accounts of the properties of brick clays in the Adelaide area have been prepared, new deposits have been examined, and successful blending methods introduced in sections of the industry. Experience with local blending problems proved of great value in helping to solve a major problem in a Victorian brick plant.

4. FOUNDRY SANDS.

(Division of Industrial Chemistry.)

A laboratory, located in the Metallury Department of the Royal Melbourne Technical College, is equipped for the study of foundry problems with special reference to moulding sands. A catalogue of Australian moulding sand deposits is maintained; during the year additional information has been gathered on new deposits, especially on suitable materials for mechanized foundries in Geelong. Deposits on the Bellarine Peninsula, close to that centre, have been surveyed. The sands are of ideal grading, but are heavily contaminated with limestone.

An investigation of the properties of Marchagee bentonite has been finalized, and the results have been published. It has been shown that this clay is a suitable substitute for the Southern-type bentonite imported from the United States of America, for incorporation in the so-called "synthetic" moulding sands.

The Section has also investigated the melting of fine metal powder recovered by ore-dressing methods from furnace spillings. A flux has been derived which will allow the recovery of up to 92 per cent. metal from mixture contaminated with 6 per cent. oxide.

5. PHYSICAL CHEMISTRY.

(Division of Industrial Chemistry.)

The properties of surfaces continue to provide fruit subjects for study in fields as diverse as the coalescer of drops, the separation of uranium from slurries by i exchange, the reduction of natural evaporation, and t mechanism of rubber reinforcement. The properties materials at high pressure, in particular the effect pressure on chemical reactions, the relation of the p perties of liquids and liquid mixtures to their molecu structure, the chemical characterization of carbons, a the fixation of nitrogen are other main lines of investi tion. The work on flotation has been terminated in or that a study may be initiated of the surface forces wh are the basis of the artificial nucleation of rain.

(*a*) *Properties of Liquids.*—Further results have be obtained in the experimental and theoretical study liquids and solutions, aimed at relating their structu with properties of importance in distillation. A n approach to the theory of simple liquids has been sho to give a satisfactory description of the critical regi of density and temperature, where earlier theories w unsatisfactory. Similar methods are being applied polar liquids and solutions. Detailed experimental stu has been made of a group of solutions of polar liqui including all possible binary combinations of acetonitri nitromethane, acetone, benzene, and carbon tetrachlori

(*b*) *The Chemical Effects of High Pressure.*—Wo in the High Pressure Laboratory has again been centr on the problem of why pressure alters the rates a equilibria of chemical reactions in the liquid phase. Co currently with a theoretical attack, a number of expe ments have been carried out to fill gaps in the existi data and to test the theoretical conclusions. The expe ments have included the first measurements of the ra of simple free-radical reactions under pressure, and so determinations of the ionization constants of we electrolytes at pressures up to 12,000 atmospheres. apparatus has been designed to extend the pressure ra to 45,000 atmospheres and some preliminary results ha been obtained at that pressure. The apparatus makes u of a new and simple form of pressure seal whi promises to be useful in other applications.

The bursting strength of thick-walled cylinders is vital factor in the design of industrial high-pressure pla A number of bursting tests have been carried out in t Laboratory and the results show that, although there is straightforward algebraic relation between the bursti pressure and the thickness of the cylinder wall, it is r at all of the kind required by the usual engineeri formulae.

(*c*) *Coalescence of Drops.*—Liquid drops floating on surface of the same liquid were studied using high-spe cinematography. The coalescence of a drop with t underlying surface or with another drop on collision delayed by the air film trapped between them. The dro were found to remain on the underlying surface for a ti proportional to their size. When two drops collide they bounced or coalesced within a time proportional the cube of the size of the smaller drop. Drops of d meter smaller than 0.05 cm. coalesced readily with oth drops, but those larger than 0.1 cm. were more likely bounce. These results have a bearing on the coalescen of colliding jets, mist, and raindrops.

(*d*) *Flotation of Tin Ores.*—An investigation of t separation of cassiterite from the Maranboy ore by flo tion has been completed. Tourmaline, which norma floats with cassiterite, has been satisfactorily depressed silico-fluoride while the flotation of fine quartz has be minimized by controlling the ferric ion content of t pulp.

The development of a novel cleaning method in which otation is coupled with hydraulic sizing has enabled 65 per cent. of the cassiterite to be recovered in a concentrate analysing 50 per cent. tin. This result was achieved in batch tests with no retreatment of middlings.

(*e*) *Rubber Reinforcement.*—Studies on the reinforcement of rubber by carbon black have been continued, particular attention being paid to the mechanism of abrasion. In a series of experiments on heat-treated carbon black, it was shown that there is a close relationship between the chemical chaarcteristics of oxygen groups in the carbon surface (phenolic, quinonoid) and the abrasion resistance of rubber compounded with these carbon blacks. Iron which is always associated with carbon blacks appears to play a dominant role in this mechanism. It has been found that strongly bound iron affords protection against abrasion. Such iron may be present either in phenolic blacks prepared at low temperature or in semiquinone blacks prepared at about 700° C.

Work is continuing on the characterization of carbons used for industrial purposes.

(*f*) *An Ion-exchange Process for the Recovery of Uranium from Ore Slurries.*—A new process of ion exchange has been developed for the direct extraction of uranium from an ore pulp. A pilot plant has been constructed and successfully operated with the financial assistance of the Australian Atomic Energy Commission and of Rio Tinto Finance & Exploration Ltd. operating through Mary Kathleen Uranium Ltd. The South Australian Department of Mines and the Permutit Co., London, have provided assistance with staff for part of the investigation.

The process may be operated batchwise or continuously. The essential feature, common to both, is the use of jigged beds of ion-exchange resins which behave like a fluid in non-turbulent flow. Pulps containing up to 40 per cent. solids may be passed through such a bed, but difficulties in removing sands from such dense suspensions have necessitated working with a pulp density of 20 to 30 per cent. solids.

In conventional practice, the feed pulp must be filtered or decanted, and a clear liquor only fed to the ion-exchange columns. More than 2 per cent. of the uranium is usually lost with the rejected solids. The resin in pulp process eliminates this step and the ion-exchange efficiency matches that of the conventional ion-exchange column. In both batch and continuous operation 99.5 per cent. of the uranium is recovered as a clear eluate five to ten times as concentrated as the feed pulp. Pulp flow rates of up to 2 gal./min./sq. ft. have been used through the adsorption column.

Negotiations are proceeding for the licensing of the patents on these processes. Much interest is also being shown in these procedures for the extraction of ores containing gold.

(*g*) *Conservation of Water.*—Further information on the use of cetyl alcohol for reducing evaporative losses from water storages has been collected.

Laboratory experiments have provided a better understanding of the techniques required for efficient spreading of monomolecular films under field conditions, and of the influence of the degree of purity of the cetyl alcohol on performance.

Field trials made in collaboration with many public water authorities and private users have shown that the most important problems to be overcome when treating large stretches of water are attrition of cetyl alcohol and damage to the floating containers. Methods of combating these faults are being investigated. From small stretches of water up to about two acres in extent the process can be expected to reduce natural evaporation by 30-70 per cent.

(*h*) *Nitrogen Fixation.*—The utilization of atmospheric nitrogen is thought to depend largely upon the activity of the enzymes nitrogenase and hydrogenase. Fifty-fold purification of the latter enzyme, obtained from the bacterium *Desulphovibrio desulphuricans*, has been achieved by a series of eleven procedures, five of which are additional to the previously published steps in hydrogenase isolation.

Tracer experiments with radio-iron and radio-cobalt fed to bacteria have shown that the most highly purified hydrogenase contains both of these metals. Although the purification is not complete, the result suggests that iron and cobalt are contained either in the hydrogenase or in an auxiliary enzyme, i.e. one which is necessary to the function of hydrogenase in the living organism.

Our understanding of the properties and nature of hydrogenase has been extended by a comparative study of the mechanism by which molecular hydrogen combines in aqueous solution with a complex cyanide of cobalt. Kinetic evidence indicates that the active complex is cobaltous hexacyanide ion.

The work has led to the first detailed proposal of how bacteria hydrogenate nitrogen gas to ammonia at ordinary temperatures and pressures and in an aqueous medium.

(*i*) *Miscellaneous.*—Preparations have been made in co-operation with other Divisions and with the Defence Standards Laboratory for preserving the Magna Carta in the National Library. A thermal conductivity gauge has been designed and constructed which will be contained with the document in a glass enclosure filled with humidified helium. The gauge will indicate when helium has completely displaced the air from the container, and after the latter is sealed will give warning if a leak should develop at a later date.

6. CHEMICAL PHYSICS.

(Division of Industrial Chemistry.)

Work has continued along four main lines, namely, (a) protein structure investigations, (b) the chemical physics of the solid state, (c) determination of molecular structure and energies, and (d) the development of new instruments and chemico-physical techniques. Considerable collaborative and service work, based on the application of the specialized instruments and techniques developed in the Chemical Physics Section, has been undertaken for industry, universities, and other parts of this Organization. Several guest workers have been accommodated for various periods during the year, both for purposes of collaboration with officers of the Section and for training in the use of specialized techniques.

Grateful acknowledgment is made to Professor N. S. Bayliss for providing accommodation for and supervising vacuum ultraviolet spectroscopic investigations and certain aspects of atomic absorption spectroscopic work.

Further progress has been made in stimulating the manufacture of specialized scientific instruments in Australia, and a commercial firm has shown interest in manufacturing several instruments based on prototypes developed in the Division. To date, royalties mounting to 53,325 dollars have been paid by an overseas manufacturer for the use of the multi-pass system in commercial infra-red spectrometers.

(*a*) *Protein Structure.*—This work is described in Chapter XVI., Section 10.

(*b*) *Chemical Physics of the Solid State.*—The theoretical and experimental study of defects in crystals and of the implications of these defects in determining the physical and chemical properties of solids has been continued.

A new symbolism for solids containing defects has been proposed.

Further calculations have been made on the energy band structure of ionic solids and its relation to the optical properties of solids. The optical properties of zinc sulphide have been interpreted in the light of the calculations.

In the field of luminescence in ionic solids, possible model mechanisms for various luminescence processes have been studied for comparison with the measurements made with the phosphorometer. The need for electronic circuits of high stability in ths field has led to the development of new types of electronic voltage stabilizers. These instruments are to be manufactured in Australia.

Theoretical work concerned with the aggregation of F-centre type defects in ionic crystal lattices is nearing completion. Apparatus for ultra-high vacuum experiments on surface reactions and catalysis, in particular for secondary electron emission experiments, has been constructed.

Measurements have been made of the rate of oxidation of the surface of molten zinc at various temperatures. Interesting features have been observed in oxide films less than 2,000 Å thick; these are of fundamental importance to an understanding of the oxidation and corrosion of metals. The need for higher accuracy at low temperatures has prompted the construction of sensitive absolute low-pressure gauges and gas-flow devices.

(*c*) *Molecular Structure Studies.*—The determination of molecular structure and the evaluation of the energetics and mechanisms of molecular processes is fundamental to much of chemistry, biochemistry, and biology.

(i) *Structure Analysis by X-ray Diffraction Methods.*—A method for determining the absolute configuration of an asymmetric molecule as well as determining its structure has been proposed.

A refinement of the structure of the 14.4 Å phase of magnesium vermiculite has been carried out. The more accurate data are intended to assist in clarifying the structural problem which has arisen with regard to the related 10.6 Å phase of magnesium vermiculite.

(ii) *Structure Analysis by Electron Diffraction Methods.*—Further measurements have been made of the dimensions of the fine-structure features of single-crystal diffraction spots given by small well-shaped crystals of magnesium oxide, and values of the inner potential and the Fourier coefficients of the potential distribution of the crystal lattice have been calculated. The accuracy of determination of inner potential has been improved, and some evidence has been found of a decrease in the effective inner potential of surface layers relative to that in the bulk of the crystal.

(iii) *Spectroscopic Studies.*—Experimental and theoretical studies of the electronic spectrum of iodine have been continued. The assignment of the electronic states has been revised and potential energy curves have been computed. To supplement this work the spectrum of the iodine ion has been studied and first-order perturbation theory has been applied to the configurations p^2 and p^4 in intermediate coupling cases.

The higher energy states of iodine and bromine are being studied by vacuum ultraviolet spectroscopy by an officer located in the Chemistry Department, University of Western Australia. Particular effort has been devoted to attempting to explain the widely differing experimental results obtained by various workers in this field and a study has been made of the effects of adsorbed layers on the windows of the absorption cell.

(iv) *Free Radical Studies.*—Preliminary experiments have shown that very great accuracy of measurement is necessary to detect free radicals produced in photochemical experiments, and to this end considerable effort has been expended on increasing the sensitivity of the small mass spectrometer and the stability of its power supplies.

(*d*) *Development of Chemico-physical Techniques.*—The development of new apparatus and new techniques is a vital part of the Section's activities, since advances in technique frequently lead to a clearer understanding of physical and chemical phenomena and often to new instruments capable of commercial exploitation.

(i) *Electron Microscopy.*—The electron microscope has been further modified to permit the recording of good-quality electron diffraction patterns from small selected areas of specimens, and this has considerably facilitated work on the systems of electron interference fringes observed in electron micrographs of superimposed lamellar crystals. Consideration of the mechanism by which these fringe patterns arise has led to recognition that the Patterson function is a form of moiré pattern. It is intended on the basis of this new interpretation of the Patterson function to examine the practicability of new methods for crystal structure analysis which it suggests.

A new type of ultramicrotome has been designed and constructed.

(ii) *X-ray Diffration.*—A simple adaptor for rotation cameras to improve the accuracy of measurement of identity periods has been designed, built, and tested. The high-temperature adaptor for powder specimens has been modified to permit the use of a rectangular X-ray beam to reduce exposure times. The construction of an automatic counter goniometer is proceeding.

(iii) *Electron Diffraction.*—The electron microdiffraction camera has been modified to improve its performance and extend its range of application. Exploratory experiments have been carried out to test the application of a new electron-multiplying device to the intensification and intensity measurement of weak diffraction patterns.

(iv) *Computers.*—Progress on the image-seeking computer has continued and in the course of this work a new technique for the design of electronic circuits has been developed. A new system has been devised for the coding of the contoured maps which form the input.

(v) *Development of New Techniques in Structure Analysis: Fourier Images and a New Formulation of Physical Optics.*—The formation of Fourier images, a new phenomenon observable when a periodic object is illuminated by radiation diverging from a small source, has been investigated theoretically, and the conclusions have been verified experimentally by using visible light and a two-dimensional photographically formed grating. The possible application of Fourier image formation to the imaging of crystal lattices in the electron microscope has been examined in detail. A small source of electrons placed close to the specimen will give magnified Fourier images of the lattice which may then be magnified by the microscope lenses. Examination of the factors controlling the resolution of the Fourier images has shown that improved overall resolution is both possible and practicable.

It has been found that the theoretical treatment can be developed much more easily and applied more readily if the conventional description of physical optics is replaced by considerations in terms of the Fourier transform and convolution concepts widely used in the theory of X-ray and electron diffraction by crystals. Generalization of this new approach has led to a reformulation of physical optics which may be applied with profit to a very wide range of problems in light and electron optics. A valuable feature is the close analogy between the theoretical steps and physical processes, which allows a graphic appreciation of the problem and simplifies its formulation and solution. It has already been shown that the new formulation simplifies the treatment of optical processes, such as the imaging by lenses, and many diffraction processes. Important applications which are being made include the theory of phase-contrast microscopy, an explanation of the effects observed when two periodic gratings are superimposed, and a new approach to the dynamic theory of electron diffraction by crystals.

(vi) *Spectroscopy.*—The technique of applying atomic sorption spectra to chemical analysis has been further eveloped. A fully automatic apparatus for multi-comonent analysis has been constructed and was exhibited "Chemex", which was held in Melbourne during May.

A study has been made of the shape of resonance lines mitted by hollow-cathode tubes and by commercial aboratory discharge lamps. Sealed-off hollow-cathode ubes for operation at liquid-air temperature have been eveloped, and the possibilities of using such tubes to rovide an international standard of length are being udied in collaboration with the Division of Metrology.

A family of double-pass instruments based on the abinet-Bunsen type of spectrograph has been designed. hese include a single-beam monochromator, a double-eam monochromator, an ozone spectrophotometer, and polychromator suitable for use in atomic absorption pectroscopy.

New types of Raman sources giving exciting lines in ne near infra-red are being tested, and the application of ne double-pass principle to Raman spectroscopy is under nvestigation.

(vii) *Mass Spectroscopy.*—Further progress in elecron-impact spectroscopy has been made by the developnent of a new design of ion source using only jig-bored tainless steel plates and sapphire balls. With this source ne energy spread in the ionizing electron beam has been educed to an effective width of 0.01 electron-volts, which s very close to the theoretical limit.

The conversion of the large mass spectrometer for the ery accurate measurement of relative isotope abundances as been successfully carried out and the O^{16}/O^{18} ratio an now be measured to an accuracy of at least 1 part in ,000, permitting the measurement of paleo-temperatures o within 1° C.

(viii) *Specialized Optics.*—A start has been made on he development of the technique and equipment for highesolution interferometry in the ultraviolet, and evaporaion equipment is under construction for producing multiayer dielectric films for use as reflective coatings in a abry-Pérot interferometer.

(*e*) *Collaborative and Service Work.*—As in previous ears the specialized facilities of the Division have been nade available through collaboration and service to indusry, universities, and other parts of this Organization. The xtent of this activity is illustrated by the following selecion of the more important problems undertaken.

(i) *Electron Microscopy.*—Extensive studies on the ipoprotein lamellar systems of cells and on the morhology of plant mitochondria; study of the proliferation f a polyhedral virus of the pasture caterpillar *Pterolocera mplicornia;* examination of two viruses of cymbidium rchids.

(ii) *X-ray Diffraction.*—Examination of rutile specinens.

(iii) *Spectroscopy.*—Infra-red study of the structure of rganic natural products, in particular, alkaloids of the *Kopsia, Alstonia,* and *Senecio* genera, hydroxysteroids, nd a wool suint acid; infra-red study of tigaso oil derivaives, of thiofluorene compounds and of carbon specimens, nalysis by infra-red methods of stearin products and of rown-coal tar derivatives; studies on the interaction etween triethylamine and ethanol. Spectra of various hototropic materials have been recorded.

(iv) *Mass Spectroscopy.*—Analysis of synthetic gases onsisting of hydrocarbon mixtures; measurement of O^{16}/O^{18} ratios in substances formed in the degradation of inacol; analysis of acetylene samples; analysis of the espiration products of apples; analysis of argon samples.

(v) *Defect Solids.*—Development of a method of monioring ultra-violet light.

(*f*) *Instrument Laboratory.*—Major items completed this year include the mass spectrometer ion chamber, diaphragm vacuum gauges, ultramicrotome, and parts for an automatic atomic absorption spectrophotometer. Extensive modifications and additions have been made to the electron diffraction camera. Progress continues on the construction of the image-seeking computer and in the development of plane diffraction gratings.

7. ORGANIC CHEMISTRY.

(Division of Industrial Chemistry.)

The research programme is principally concerned with the following projects: the investigation of the chemistry of wool wax and suint with a view to their wider industrial utilization; the utilization of sugar-cane wax; the examination of Australian plants for pharmaceutically valuable alkaloids or substances toxic to livestock; the investigation of long-chain compounds with special reference to oils and fats and their derivatives; and research on synthetic resins and raw materials for the resins and plastics industry.

(*a*) *Wool Wax and Suint.*—This work is described in Chapter XVI., Section 4.

(*b*) *Sugar-cane Wax.*—The examination of solvents for separating the useful hard wax fraction from crude cane wax has shown that of the single solvents, *iso*propanol and acetone were most satisfactory from the combined technical and economic aspects. The first of these is not produced in Australia, and the second has the disadvantage that it is satisfactory only when used under pressure. These considerations suggested that the obvious disadvantages in the use of a solvent mixture might be outweighed if both constituents were readily available. It has been found that certain mixtures of ethanol with either benzene or a petroleum fraction can be used at atmospheric pressure to isolate a hard wax fraction. Unlike the crude wax, the hard wax obtained responds well to bleaching with small amounts of charcoal and to oxidation of coloured impurities by air. Pale waxes can be prepared similar to those made with the use of *iso*propanol. A patent application covering this method of refining has been filed.

(*c*) *Plant Alkaloids.*—Negotiations with certain pharmaceutical firms aimed at placing the systematic pharmacological screening of Australian and New Guinea plants on a sound collaborative basis were reported last year. These negotiations have been satisfactorily concluded, and a programme of work has been initiated with Smith, Kline & French Laboratories of Philadelphia, United States of America. Emphasis is at present being placed on the testing of total alkaloidal extracts from certain families of plants, though extracts from alkaloid-free species of reputed medicinal value are also being examined. Preliminary results are encouraging, two of the first three extracts submitted exhibiting activities which warrant separation of the component alkaloids for more detailed testing. The co-operation of the Land Research and Regional Survey Section and the New Guinea Department of Forests has made possible the examination of a number of New Guinea species.

The reviving interest in plants as sources of new drugs or of information which may help in the development of new drugs has been reflected in the number of requests from overseas organizations for assistance in the collection of plant materials. It is the policy of the Division to encourage the widest possible examination of Australia's natural resources and to meet, as far as possible, requests for plant materials from local or overseas organizations. To this end a field botanist has been appointed to the staff of the Division. He will operate under the supervision of an officer of the Division of Plant Industry. During the past few years samples of many Australian plants have been sent to the U.S. National Cancer Institute for antitumor testing, and extracts of several of these have brought about some degree of regression in the test tumor. Arrangements have now been made with the Victorian Cancer Institute Board for such testing to be carried out by the Board in Melbourne, and it is expected to commence shortly.

An examination of *Alstonia constricta* alkaloids has been continued. Acute toxicity tests carried out in the Department of Pharmacology, University of Melbourne, have shown the toxicity of a concentrate to be low; chronic toxicity tests and the examination of the tranquillizing effect are in progress. A number of *Alstonia* spp. from Australia, New Guinea, and New Caledonia have been examined, but only *A. constricta* contains reserpine or other bases giving non-volatile acids on hydrolysis. Work has also continued on the alkaloids of the apocynaceous species *Kopsia longiflora* of *Lunasia amara,* and on the vesicant alkaloid cryptopleurine. The relation of the latter to "*iso*cryptopleurine", the structure of which had previously been determined by X-ray crystallographic analysis, has now been established. Using a radio-active tracer technique it has been shown that "*iso*cryptopleurine" methiodide is, in fact, racemic cryptopleurine methiodide. A study of canadine and related alkaloids has thrown light on the mechanism of racemization of cryptopleurine methiodide under conditions expected to bring about a Hofmann degradation.

(*d*) *Stock Poisons.*—The study of pyrrolizidine alkaloids again constitutes the major part of this programme. Substantial amounts of monocrotaline and a new alkaloid which is an *O*-acetylmonocrotaline have been found in Queensland specimens of *Crotalaria spectabilis,* which is therefore a danger to stock and potentially capable of giving rise to Kimberley horse disease. Two alkaloids isolated from *Crotalaria trifoliastrum* are of interest, since they constitute a new type of pyrrolizidine derivative and since *C. trifoliastrum* has been shown by prolonged feeding trials to be harmless to horses. In these alkaloids the pyrrolizidine nucleus is etherified rather than esterified, one of the alkaloids being *O*-methylsupinidine. The structure of a minor alkaloid of *Crotalaria retusa* is under examination; it has been shown to be an ester based on dihydroanhydro-monocrotalic acid.

Progress has been made towards elucidation of the structures of the alkaloids of *Senecio jacobea* (ragwort). Jacobine and jaconine are related, being interconvertible by addition and loss of hydrogen chloride, and both are hydrolysed to a mixture of two isomeric acids. One of these acids, jaconecic acid, has been degraded to α, β-dimethyl malic acid, and this, together with other data, enables a structure to be put forward for the acid. The formation of a chlorine-containing dilactone by acid hydrolysis of jacobine accords with the proposed structure.

The structures of two alkaloids of *Echium plantagineum* (Paterson's curse) have been established. Both have a retronecine nucleus and angelic acid as one esterifying acid. The second acid of echiumine is trachelanthic acid and of echimidine is a trihydroxy acid, echimidinic acid. Heliosupine, previously obtained from Russian *Heliotropium supinum,* has been isolated from *H. supinum* growing in Victoria, and its structure confirmed as a diastereoisomer of echimidine.

Structural work on the seed alkaloids of the Western Australian blue lupin is nearing completion, and has shed light on the relationship between basic strength and stereochemistry in the sparteine group of alkaloids. The results suggest that some previously assigned structures are incorrect, and it is expected that the information obtained will be of value in determining the structure of new members of the group.

Poison plants under examination in which the toxicity is not due to alkaloidal constituents are *Atalaya hemiglauca, Indigofera enneaphylla,* and *Phalaris tuberosa.* Difficulties with supply of material and biological testing have retarded progress with the two latter problems. Efforts are being made to obtain supplies of active *Phalaris* from districts other than Coonalpyn Downs. Progress has been made with the isolation of the toxic principle of *Atalaya hemiglauca.* The toxicity has been shown to be due to water-soluble materials of an amphoteric nature.

(*e*) *Root Exudates.*—It has been believed for a very long time that plants growing side by side can influence the growth of one another. In recent years evidence has accumulated that one means by which such influence is exerted is through the excretion of substances from the root system into the soil. In fact, root exudates are known to be involved in other than plant/plant interactions. They play an important part in the life cycle of certain parasitic plants, of nematodes, and of microorganisms, and consequently are of profound economic significance. They have been shown to be implicated in nodule formation on the roots of nitrogen-fixing legumes, and there is reason to believe that, directly or indirectly, they may play a part in the uptake of nutrients from the soil. Very little conclusive chemical work has been done on root exudates, and in view of their significance to agriculture a project has now commenced with the aim of isolating and identifying biologically important constituents of them.

(*f*) *Fats and Related Long-chain Aliphatic Compounds.*—The examination of the seed fat of *Mallotus philippinensis* of Australian origin for its potential use as a drying oil is being continued, and a survey of other native *Mallotus* species is in progress. Two other species so far examined, *M. discolor* and *M. claoxyloides,* are both similar to *M. philippinensis* in containing as major constituent acid the triene hydroxyacid, kamloenic acid.

During the year an experimental extraction and refining of safflower oil was made on 10 cwt. of seed grown by the Division on Plant Industry during 1954 in Australia. The seed was lightly crushed, extracted with light petroleum, and yielded 25 per cent. of its weight as oil, less than 1 per cent. remaining in the exhausted seed. The oil was easily refined and bleached by customary methods to a product that had a good colour (Gardner number 2-3) and a low acid value (0.02 per cent.). Trial samples have been submitted to paint and varnish manufacturers to obtain information about the amount of this oil that could be used.

Work continues on the preparation of long-chain compounds derived from oleic and other unsaturated fatty acids, the present demand for which is disappointing. Performic acid oxidation of the ketones obtained from these acids gives tetrahydroxyketones which may alternatively be obtained in a reverse sequence of operations, by ketonization of the dihydroxystearic or other acid via the acid chloride. Oxidation of the tetrahydroxyacids yields ketodibasic acids.

There has recently been considerable interest in a group of naturally occurring long-chain polyunsaturated amides with potent insecticidal properties, e.g., pellitorine and herculin. A project has been commenced which will examine the possibilities of synthesizing these or related compounds of insecticidal value, with the use of long-chain compounds coming from the fat and oil industries as starting materials.

In conjunction with the Chemical Physics Section a preliminary investigation was made of the extent of geometrical isomerization of unsaturated fatty acids during the commercial conversion of tallow to stearin and olein.

(*g*) *Tigaso Oil.*—Work is proceeding on the constitution of the optically active, nonphenolic component of the oil exuded from the New Guinea tree *Campnospermum brevipetiolatum.*

(*h*) *Tannin Formaldehyde Adhesives.*—Plywood adhesives made from tannin extracts were developed in the Organic Chemistry Section several years ago, and work was suspended when their possibilities had been demonstrated. During the past year a tannin not included in the arlier tests, viz., mangrove cutch, has become a likely ource for commercial supplies for adhesive use; work was herefore resumed on this material in collaboration with he Division of Forest Products. The suitability of the annin was quickly shown, and detailed work was carried ut to overcome weaknesses. It was found that additions f polyvinyl acetate emulsion improved the joint strength udged both by wood failure and by shear tests after oaking the plywood in hot water. Work is continuing with every expectation of formulating an adhesive which will be commercially acceptable for high-quality plywood. There is commercial interest in this project.

(*i*) *Constituents of Brown-coal Tar Acids.*—Very little s known about the detailed composition of the tars to be obtained from Morwell or Yallourn brown coal, either by gasification or carbonization. Some of the facilities of he Division are being used to assist the Gas and Fuel Corporation of Victoria in this complex analysis. A start has been made by condensing the effluent from the pilot carbonization plant at the Engineering School of Melbourne University. The product thus obtained has been extracted, and the tar acids have been fractionated. Work s proceeding on suitable methods for determination of he constituent phenols. When tars are available from he Lurgi pressure gasification plant the analysis will be carried out in close collaboration with the Gas and Fuel Corporation.

Various techniques will be used in treating the Lurgi tar oils, including distillation, adsorption, and extraction. A large-scale adsorption chromatography unit is to be built for the separation of hydrocarbons. Fractionation of phenols by liquid-liquid extraction is being investigated as a possible alternative method to distillation.

(*j*) *Microanalytical Laboratory.*—Some 5,000 analyses were carried out by the Microanalytical Laboratory in the past year, at the request of Divisions and other Commonwealth laboratories, universities, and industrial laboratories. A gratifying feature has been the increasing extent to which the service is being used by universities outside Australia, principally in Asian countries. Some analyses have even been requested from England and America, where there is no lack of well-established microanalytical services.

(*k*) *Miscellaneous.*—An all-glass photoelectrically operated dispenser for use separately or in conjunction with a fraction collector has been designed which is capable of delivering constant volumes irrespective of changes in density or rate of inflow of liquid from chromatographic columns. Its possible application in industry for accurate repetitive filling is under examination.

8. CHEMICAL ENGINEERING.

(Division of Industrial Chemistry.)

The current research projects are mainly concerned with the utilization of brown coal, development and application of the technique of the fluidization of solids, and the utilization of solar energy. The facilities of the Process Equipment Laboratory continue to be fully employed on a wide range of short-term investigations of unit operations and chemical processes, undertaken in co-operation with industrial companies and other Sections of C.S.I.R.O.

(*a*) *Utilization of Brown Coal.*—Particular attention continues to be given to the investigation of the kinetics of the chemical reactions which occur when brown coal is gasified in a pressure generator. This work is described in Chapter XX., Section 6.

(*b*) *Fluidization of Solids.*—Research on fluidized solids systems includes basic studies of the characteristics of fluidized beds, the accumulation of data for the design of large fluidized bed reactors, and a pilot-plant investigation of the fluidized bed roasting of copper concentrates.

(i) *Characteristics of Fluidized Beds.*—The present emphasis in the basic research programme on the properties of fluidized solids systems is on the study of gas bubbles in fluidized beds. In this work the object is to determine how bubbles form and grow, and what effect they have on the degree of solids mixing, and the efficiency of gas-solids contacting.

In connexion with the development of the multi-cone air distributor for the pilot-plant roaster (referred to under next heading), a considerable number of fluidization tests in large-scale models have been performed. These tests permitted the determination of the optimum size and shape of cones to ensure satisfactory fluidization of particles of varying size range, and provided information on the factors influencing the uniformity of air distribution in units of large cross-sectional area. This information has been incorporated in a design for a commercial-size fluidized bed roaster employing the multi-cone principle.

(ii) *Fluid Bed Roasting of Copper Concentrates.*—This pilot-plant investigation comprises the first part of a co-operative project with Mt. Morgan Ltd. and the Mt. Lyell Mining and Railway Co. Ltd., the object of which is to evaluate a hydrometallurgical process for the recovery of copper and precious metals from sulphide concentrates. The process consists of the controlled roasting of the concentrates to convert the copper into a form soluble in dilute sulphuric acid, the leaching of the calcines, and the electrodeposition of the copper from the leach solutions. The precious metals which remain in the residues are recovered by cyanidation.

During the year a large number of runs of the 3-ft. 6-in. diameter pilot-plant roaster were performed to investigate the influence of the roasting temperature, the proportion of excess air, the grade of concentrate, the feed rate, and various aspects of roaster design on the calcine composition and properties. It has been demonstrated that calcines with very favourable leaching properties, i.e. high copper extraction, low iron extraction, and high acid consumption, can be produced by suitable choice of the operating conditions. Runs aimed at the production of calcines for reverberatory furnace smelting have also been most successful.

Operating difficulties caused by the agglomeration of calcine particles in the fluidized bed have been completely overcome by the development of a new design of roaster bottom, i.e. the multi-cone air distributor. In this design the number of tuyeres through which the fluidizing air is introduced is much reduced, and each is placed at the bottom of an inverted narrow-angle hollow cone moulded in the refractory concrete hearth of the roaster. The upper ends of the cones are developed to fit together into a hexagonal pattern with a minimum of flat surface between them. Thus the air velocity in the lower portion of the bed increases greatly towards the air entry point, and this prevents the defluidization of large agglomerated particles which would otherwise segregate and sinter together into troublesome accretions. Experimental runs have shown that a roaster constructed in this way is, in addition, very much more flexible with regard to throughput, and enables better control to be obtained over calcine composition. A patent covering this development has been sought.

The major objects of the current experimental programme have now been achieved. A small experimental roaster (12-in. diameter) has been constructed to enable a more detailed study to be made of some aspects of the chemistry of the roasting process, and to provide for roasting tests on special types of concentrates which are available only in small quantities.

The two other major copper producers in Australia, Mt. Isa Mines Ltd. and Peko Mines N.L. Ltd., have now become associated with this project.

(*c*) *Process Equipment Laboratory.*—This laboratory provides facilities for technological experiments and the rapid development of new chemical processes to the pilot-plant stage. The technical staff of the laboratory advise on the design of the experiments and supervise the use of the equipment by the staff of the organizations which initiate the work. Seventeen projects have been conducted this year for private industry and eight for other Sections and Divisions.

The utilization of solar energy is also being studied on a part-time basis. After successful modification of the Gomella and Telkes stills, a large installation for watering sheep in remote locations has been designed. By storing water distilled during the winter months, and also any rain falling on the stills, enough fresh water will be available for blending with saline water to provide for the total needs of 100-150 sheep throughout the year. The plant will cost approximately £500.

XIX. MINERAGRAPHY AND ORE-DRESSING.

1. General.

The importance of investigations for the development of the mining industry and the utilization of Australia's mineral resources is fully recognized by the Organization.

Mineragraphic work to provide information on the mineral composition of ores has been in progress in Melbourne since 1927. The techniques used are highly specialized and require considerable experience, so that it is only rarely that they can be applied by the staffs of operating mines. The current work of the Mineragraphic Investigations Section is described in Section 2 of this Chapter.

The Ore-dressing Laboratories operated in Melbourne in collaboration with the University Department of Mining, and in Kalgoorlie in co-operation with the School of Mines, investigate the composition of ores and provide advice on suitable methods for their full-scale treatment. This work is reported in Sections 3 and 4 of this Chapter.

Work on the utilization of minerals is carried out by the Division of Industrial Chemistry (*see* Chapter XVIII., Section 2).

2. Mineragraphic Investigations.

(Mineragraphic Investigations Unit.)

(*a*) *Administrative.*—Dr. Stillwell worked in the Laboratories throughout the year on a study of the mineralogy of the Broken Hill lode, undertaken by Mineragraphic Investigations in conjunction with the Broken Hill Geological Research Committee. Mr. K. J. Callow, another officer of the Research Committee, worked on Broken Hill petrological problems in the Laboratories from September, 1955, to the end of the year. Dr. S. Salamy, of the Broken Hill Proprietary Co. Ltd., was provided with facilities to study the mineralogy of South Australian taconites, for a period of two months, and Dr. K. Banerji, of Calcutta University, came to the Section in June, 1956, for a short period of instruction in mineragraphy.

The investigations have been facilitated by contributions from a number of mining companies through the Australasian Institute of Mining and Metallurgy. The University of Melbourne has co-operated in providing laboratory accommodation.

(*b*) *Investigational.*—Thirty-two investigations have been made of the mineral associations of ores, rocks, drill cores, and mill products submitted by mining companies and other organizations.

Studies of the uranium minerals and associated rare earth minerals at the Mary Kathleen leases and adjacent prospects, in the Cloncurry district, Queensland, have continued.

The investigation of sand drift along the beaches nea Portland, Victoria, for the Portland Harbour Trust wa completed by following the movements of indicato minerals placed at various significant points along th coast. The indicator minerals could be detected in concentrations as low as one part in ten million. Movemen of sand eastwards from Cape Bridgewater was extremel rapid during the period of the tests, amounting to abou one mile per day. This sand crossed the mouth o Portland Bay, and did not penetrate to the Harbour area

Copper-nickel ore from near Zeehan, Tasmania, wa found to contain significant quantities of two unusua nickel minerals, millerite and violarite, in association wit chalcopyrite. Ore from the Pioneer Mine, Hatches Creek Northern Territory, consisted of an association of bismut telluride, bismuthinite, and native bismuth, together wit other sulphides, and interleaved wolfram and scheelite Ore specimens, mill products, and specimens of matte an bullion from the Northern Hercules Mine, Norther Territory, were examined.

A comprehensive survey was made of the mineralization in the Aberfoyle tin mine, Tasmania, with specia reference to variation of mineralization with increasin depth of the veins.

The rare mineral pyrosmalite, and its variations, wer identified in the Broken Hill lode, and described. A study of the manganese and iron contents of sphalerit from the Broken Hill lode revealed local variations, an an overall pattern of variation bearing a genera resemblance to the distribution of cadmium in the lode A petrographical study of Broken Hill amphibolite showed that those in the Broken Hill Basin are of igneou origin, while those at Peak Hill and Silver Rock represen metamorphosed impure limestones and dolomites. Th igneous amphibolites show retrograde metamorphis from pyroxene granulite.

An extensive oolitic iron formation in Arnhem Lan was studied in conjunction with the Melbourne Ore-dressing Laboratory to determine whether it could b concentrated to better than 60 per cent. iron grade; an a visit was paid to Yampi Sound to study the taconit formations there.

3. Ore-dressing Investigations.

(Melbourne Laboratory.)

(*a*) *Administrative.*—The Officer-in-Charge, Associat Professor H. H. Dunkin, commenced on an overseas tou in February. After visiting mines, plants, laboratories and universities in South Africa, United Kingdom, Unite States of America, and Canada, he is expected to retur late in July.

New equipment acquired during the year include replacement of the intermediate crusher by a sturdie model, and purchase of a high-intensity magnetic separato and a volumeter, an instrument for measuring the volum of granular solids by compression of interstitial air.

The work of the Section will be greatly facilitated b a substantial gift recently from Consolidated Zinc Pty Ltd.

(*b*) *Investigational.*—The character of the ores investigated in the Section continues to be widely varied Investigations during the year included work on ores o copper, cobalt, nickel, lead, tungsten, tin, and gold, an on beach sands and phosphate rock.

An alternative method of separating sulphides from King Island scheelite concentrates by electrostatic separation was investigated; a plant utilizing the process was later installed and is operating successfully.

Another extensive investigation almost completed i concerned with the preparation of separate concentrate of wolfram, scheelite, and bismuth from a mixed concentrate from a mine in the Northern Territory. Magnetic concentration and flotation are the methods employed and the increased revenue from the new processes seem likely to repay the cost of the plant within three years.

Investigations aiming to extend the beach sand mining dustry and to improve concentrating methods continue. detailed investigation of monazite recovery was comleted, chrome-free ilmenite deposits in Western Australia xamined, and a report on laboratory separators issued.

The flotation behaviour of a new type of base metal re containing readily flotable gangue was being investiated throughout the year. This work is continuing on n accelerated basis with financial assistance from a eading Australian mining company.

The treatment of cobaltiferous manganese ores by presure leaching is being currently studied in a graduate esearch project co-operatively directed by the Mining epartment of the University and this Section.

An investigation into the principles governing concentraion on the Denver Buckman table was started during the ear. Most of the work was done by a Colombo plan isitor from the Malayan Department of Mines, who spent few months in the laboratory. It is hoped to continue he work during the current year.

To provide a comparison with work on the flotation f a tin ore conducted at the Division of Industrial hemistry, a detailed examination of the behaviour of the ame ore in gravity concentration was conducted in this ection.

4. ORE-DRESSING INVESTIGATIONS.

(Kalgoorlie Laboratory.)

Eighteen Reports of Investigations and 76 Certificates ere issued from the Kalgoorlie Laboratory. Eight of he Reports of Investigations referred to gold ores, three o the ores of other metals, and seven to non-metallics. The Certificates recorded mainly assays and analyses, and ncluded many gold assays for the Government Geologist. The Geological Survey has an extensive drilling proramme in progress at the present time, and all assays and est work are being done in the Kalgoorlie Laboratory.

High-grade lime sands are available near Perth, and o enable a better grade of lime to be produced some ork was done on these. A 4-in. diameter fluid bed reactor was constructed, and the lime sands were calcined at temperatures of 850-950° C. Some trouble was experienced with sinter formed from siliceous matter present in the lime sands. Carbon dioxide elimination was above 94 per cent., and provided the temperature was kept below 900° C., sinter formation was not serious.

At Christmas Island the top layer of phosphate rock contains too much iron and aluminium for use as a raw material in the making of superphosphate, and very large quantities are being removed and stockpiled. A successful method of reducing the iron and aluminium to acceptable limits was developed, and recommendations were made for pilot-plant work.

Comprehensive test work was carried out on drill cores from the pyrite and magnetite ore bodies at Koolyanobbing, about 40 miles from Southern Cross. The pyrite and the magnetite were extremely fine-grained, and it was necessary to grind the ore fine before reasonable-grade concentrates could be produced. Magnetite concentrates assaying 51-61 per cent. iron and pyrite concentrates assaying 47 per cent. sulphur were produced after grinding to minus 100 mesh.

Work on accumulated flotation tailings from the Blue Spec Mine, Nullagine, showed that the cyanidation pulp would be extremely difficult to filter and to thicken. Scheelite concentrates assaying 70 per cent. tungstic oxide and containing approximately 60 per cent. of the tungsten in the ore were obtained by gravity concentration followed by a complex magnetic roasting and separation technique.

An ilmenite concentrate assaying 55.4 per cent. titanium dioxide and less than 0.08 per cent. chromic oxide was produced from a beach sand from Wonnerup by table concentration followed by magnetic separation. A mixed garnet-rutile-zircon product was also obtained, which would possibly yield clean rutile and clean zircon concentrates by electrostatic separation.

Test work on ore samples from the Northern Hercules Mine, Pine Creek, showed that the plant designed and under construction would be suitable for treating ore similar to the sample supplied. The plant design was from work done in the Kalgoorlie Laboratory in 1937, and the present work was a check test.

Modifications to an existing plant treating lead-zinc ore from the Napier Range, Western Australia, were recommended as a result of test work on the ore and on some Wilfley Table concentrates. Tabling appeared the most satisfactory method of concentration, but the plant required the addition of a mill for fine grinding and a classifier. The Laboratory staff co-operated with the mill superintendent of a Kalgoorlie mine to test a laboratory-scale, Edwards-type roaster differing in some features from the type now in use. The roaster was designed by the mill superintendent, and built on the mine. Laboratory tests and subsequent pilot-plant scale tests were satisfactory, and a full-scale roaster of the same design is now under construction.

At the time of writing pilot-scale test work on a graphite ore from Munglinup is in progress. The process is based on batch work previously done in the Laboratory, and confirms the results so obtained. The work is not yet complete, but present indications are that a concentrate of good marketable grade is being produced. Large quantities of ore are said to be available, and if a satisfactory market can be found for the product a new industry will have been established in Western Australia.

XX. FUEL.

1. GENERAL.

The Organization's fuel research programme is at present mainly confined to coal, which is the most important primary fuel available in Australia. There is insufficient knowledge concerning the properties and characteristics of Australian coals, and an urgent need for this knowledge exists so that the best and fullest use may be made of the available resources.

The Organization's main centre for investigations on fuels is the Coal Research Section, located at North Ryde, New South Wales. This Section was established to undertake, on a national basis, a long-term fundamental and comprehensive study of the physical and chemical characteristics of Australian coals. The work of the Section is reported in Sections 2-4 of this Chapter.

The Division of Industrial Chemistry undertakes work on the engineering aspects of gasification of low-rank coals (*see* Section 6 of this Chapter).

Co-operative investigations on the fossil pollens in brown coal are undertaken in the Botany School of the University of Melbourne (*see* Section 5 of this Chapter).

Coal Research Section.—The programme of work of the Coal Research Section includes a detailed survey of the chemical and physical properties of all Australian coal resources; delineation of their peculiarities to enable the best mode of utilization to be chosen according to the latest advances in fuel technology; coal washing and similar investigations to improve the coking properties of coals and to reduce their sulphur and ash contents; the assessment of the gas-making properties of coals; fundamental studies in the petrological and chemical constitution of coal and coke; composition and utilization of coal tars; standardization of sampling, sizing, testing, and analytical techniques as applied to solid fuels.

During the year some progress was also made towards recruiting research and technical staff although the position is still far from satisfactory, especially as regards staff with training or experience in fuel technology.

Owing to restrictions imposed by limited funds and the shortage of staff with experience in fuel technology, the work on the combustion characteristics and mechanical properties of Australian coals has had to be temporarily discontinued.

A two-day symposium on " The Production, Properties and Utilization of Foundry Coke " was held in the Section towards the end of the year.

The Officer-in-Charge attended the Fifth World Power Conference in Vienna during June. In his capacity as Australian member of the Commonwealth Committee on Fuel Research, the Officer-in-Charge continues to act as co-ordinator of reviews of fuel research carried out by official fuel research centres throughout the British Commonwealth and dealing with (*a*) physical testing of coal and petrographic investigations, and (*b*) brown and sub-bituminous coals.

During the previous year Dr. D. T. A. Townend, C.B.E., Director-General of the British Coal Utilization Research Association, visited Australia to advise the Organization on its coal research programme. During the year under review his report was published in which he emphasized the need for the rapid organization by the Australian coal industry of proper scientific and technical control of production in which the Coal Research Section could materially assist.

2. Examination of Coal Seams.

(Coal Research Section.)

The detailed survey of the chemical and physical characteristics of selected coal seams and their sub-sections continued as in previous years. Coals were examined from the following seams in the Northern Coalfield of New South Wales: Young Wallsend seam (Stockton Borehole Colliery), Main Greta seam (Aberdare Colliery), and Victoria Tunnel seam (Burwood Colliery). In the Southern Coalfield of New South Wales coal from the Wanganderry mine in the Upper Burragorang Valley (uncorrelated seam) was examined.

In Queensland samples were obtained from the Bowen and Blake seams (Bowen Consolidated Coal Mine) and examination of these is proceeding. Samples from the Dawson and Dunstan seam (Dawson Valley Colliery), and also from a series of exploratory bores sunk in this area by Mount Morgan Ltd., were examined.

A valuable source of germanium overseas is the flue dust from certain steam generators and gas producers. In order to evaluate the possibilities in Australia the germanium content of a large number of samples of New South Wales bituminous coals, Victorian brown coals, and Western Australian sub-bituminous coals has been determined, as part of the survey programme.

3. Coal Constitution.

(Coal Research Section.)

(*a*) *Petrography*.—Petrographic studies form an important part of the investigations into the chemical, physical, and mechanical properties of coal, and of its behaviour under various conditions such as storage, grinding, and carbonizing.

Studies of the petrographic structure of commercially important New South Wales coal seams have been continued, although recent decisions of the International Commission for Coal Petrography have necessitated modifications of the terminology previously used. Adoption of the revised nomenclature, however, has the advantage of enabling rapid and direct comparisons with results published overseas.

Polished blocks representing the full thickness of the Lithgow Seam and Kandos Colliery have been examined, and a survey of the petrography of the seam of the Illawarra Coalfield has also been undertaken. In the latter project the volumetric proportions of the microlithotypes in seam profiles were estimated by a point counting technique. Petrographic data have been obtained for seventeen seam profiles of the Bulli seam, eleven of the Wongawilli, and three and one respectively of the Tongarra and Woonona seams.

(*b*) *Palynology*.—The basic taxonomic work on Australian Permian spores has now been completed, although the final descriptive paper on trilete spores of the pteridophyte type is still awaiting publication. Considerable progress has also been made on the collating of information on the distribution of the more common Permian forms in Australian sediments. In New South Wales four boreholes from the Tomago Stage have been examined, while samples from Collie, Eradu, and the Kimberley area have added to the record of the cataloguing of the Permian spores in Western Australia. In addition a suite of samples from an oil drilling at Kurrajong, New South Wales, has provided palynological data on the Triassic and Permian sediments of the Blue Mountains districts.

Palynological techniques are being applied to correlation problems in the Young Wallsend-Borehole Group of seams from the Northern Coalfield of New South Wales.

(*c*) *Physical and Chemical Properties*.—(i) In an investigation of the variation of internal surface with carbonizing temperature it has been found that the specific surface of cokes and chars, calculated from nitrogen adsorption isotherms obtained at 78° K., reaches a maximum in samples prepared at about 700° C. With many cokes it was impossible to obtain an accurate nitrogen isotherm owing to very slow attainment of equilibrium. The sorption of water vapour by such samples was found to be rapid and sorption isotherms of water vapour were measured by a gravimetric method using fused quartz or tungsten springs.

A separate apparatus has been erected for measuring the specific volume of coals and cokes by displacement of helium. Porosities of such materials have been calculated from their displacements of mercury and organic liquids.

(ii) The changes in the X-ray diffraction patterns of cokes and chars that occur with rising carbonization temperature have been studied. For high-rank coking coals there appeared to be a steady increase in the dimensions of graphitic " crystallites " above 700° C., but it was difficult to interpret the more irregular changes in the diffraction patterns of lower-rank coals in terms of graphitic structures. Preliminary examinations have been made of the effects on the diffraction patterns of the blending of coals and of varying the rate of increase of temperature.

Fourier integral analysis of the diffraction data of a metallurgical coke gave a radial distribution curve similar to that of graphite, but with several peaks unresolved.

(iii) An investigation of the chemical mechanism of the formation of coke from coal has been started with the study of the pyrolysis of a number of pure organic compounds that form cokes, a recording thermobalance being used.

(iv) The work on acidic oxygen-containing groups in coals was completed. This work has shown that in a range of coals of carbon content between 67 and 92 per cent. (d.m.f.) the acidity falls from about 4.5 to 0.2 milliequivalents per g. with increasing carbon content. The reactions of oxygen-containing groups in brown coals have been studied, and it has been shown that over ninety per cent. of the oxygen in several coals appears to be present in the form of reactive functional groups.

(v) Well-defined infra-red spectra of brown coals, their reaction products, and their chars were obtained by using the potassium halide disk technique.

4. COAL UTILIZATION.

(Coal Research Section.)

(*a*) *Combustion Investigations.*—As mentioned preously, owing to lack of funds and shortage of staff, the ork of this group has had to be temporarily curtailed. owever, some of the investigations undertaken previously ere completed and reported.

(i) The results of combustion studies with Victorian own coals were presented at the 1955 A.N.Z.A.A.S. eeting in Melbourne. Under conditions of *overfeed* ombustion simulating spreader-stoker firing, satisfactory ombustion of brown coals containing up to 62 per cent. oisture was achieved. The primary air required for ficient combustion was about 75 to 80 per cent. of the eoretical air necessary for the complete combustion of ese coals. Heat release rates of up to 750,000 B.t.u./sq. ./hr. were obtained.

(ii) The combustion behaviour of Leigh Creek coal as studied under conditions simulating overfeed comustion. It was found that while under travelling grate onditions the maximum practicable rate of heat release as of the order of 3 therms/sq.ft./hr., with the *overfeed* ethod of combustion this rate of heat release could be oubled.

(iii) To obtain a better understanding of the comustion behaviour of coal in fuel beds, an investigation vas carried out into the relationship between air flow and ressure drop through fuel beds. This work has helped onsiderably to elucidate the relationship between coal ines, surface moisture, fuel bed structure, and pressure rop.

(iv) The results of an investigation on the influence f some of the physical factors controlling the comustion behaviour of three typical New South Wales coals, Lithgow, Greta, and Bulli, have now been evaluated. The ollowing variables have been studied: (1) coal type, (2) ate of air flow, (3) size grading and the influence of ines, (4) surface moisture, (5) depth of fuel bed, and (6) lagging and clinkering characteristics.

(v) An index of combustibility has been developed to ndicate the ease of burning coal in which the following hree parameters are used: (a) the net heat released at given rate of air flow; (b) the amount of air supplied luring combustion; and (c) the loss due to unconsumed ombustible matter.

(*b*) *Carbonization Investigations.*—(i) *Tests in Caronizing Plant.*—In further studies of the gas and coke naking properties of Australian coals and their blends, bout 80 pilot-scale carbonizing tests have been carried ut over the past year using the B.M.–A.G.A. coking nit. In this plant test charges of 100 and 200 lb. have een carbonized at temperatures between 500 and 1,000° C. under closely controlled conditions, and the quantity nd quality of the products examined in detail.

An important part of this work has been the blending f coking coals with poorly coking coals and inert naterial, such as low temperature char, in order to mprove the quality of metallurgical coke and to extend upplies of the good-quality coking coals by using coals ormally regarded as unsuitable. Coals from the Bulli nd Wongawilli seams on the south coast of New South Wales have been studied in this way.

Other work has included the routine evaluation of the arbonizing properties of prepared samples from two eams, namely, the Greta and Victoria Tunnel, as part f the coal survey programme. Weathering tests to study he effect of prolonged storage of graded coal samples, aken from the Borehole, Muswellbrook, and Greta seams, n their carbonizing behaviour are still in progress.

Much of this work, particularly the blending experiments, has been supported by plasticity measurements nd petrographic examination, as the caking properties and distribution of the coal macerals are of profound importance in coke-making.

(ii) *Fundamental Coking Phenomena.*—Investigations of a more fundamental nature into coking phenomena are proceeding. The relation between softening process of coal and its subsequent decomposition during carbonization is considered to be of great significance in assessing the relative coking properties of coals, and in determining the physical structure of the coke product. Preliminary work completed so far indicates that the relation between the plasticity of a number of coals, as measured by the Gieseler plastometer, and the rate of weight loss, as a measure of the decomposition rate during uniform heating, is significant in coking behaviour.

A new type of automatic recording balance, described as a differential thermogravimetric balance, has been designed to measure this rate of thermal decomposition directly. This apparatus has also found useful application in other fields of work, including kinetic studies of coal pyrolysis and the combustion of coal. The balance can record total weight changes of up to 0.5 g. at a maximum rate of 30 mg. per min.; the cumulative weight change may be read to an accuracy of less than 1 mg., and the differential weight change may be determined to within 0.2 mg. per min. A linear heating-rate temperature controller, which is fully proportionating, has also been devised for these studies.

As an integral part of this investigation into fundamental coking phenomena, petrographic examinations of carbonization products were made in order to gain a deeper insight into the mechanism of coke formation during carbonization. Retorts were withdrawn from the B.M.-A.G.A. furnace before the coal charge was completely carbonized and were rapidly quenched and cooled. Microscopic examination of the polished sections of samples so obtained illustrated very clearly the commencement of the formation of gas vesicles and the deformation and coalescence of the particles of the various coal microlithotypes as they were converted into coke. The plastic zone over which the transformation takes place appears to be only a few millimeteres thick.

(*c*) *Coal Tar Investigations.*—To evaluate further the utilization of chemicals from coal and as an essential part of the above carbonization programme, investigations are continuing on the properties and constitution of coal tars.

Analyses have been carried out on tars, aqueous liquors, and scrubber naphthas from 35 carbonization experiments in the B.M.-A.G.A. pilot plant. An apparatus is being assembled for the analysis of scrubber naphthas and coal tar fractions by chromatography in the vapour phase.

Representative Australian coke oven and continuous vertical retort tars have been separted into pitch and acidic, basic, and neutral oils. The oils are being fractionated in high-efficiency distillation columns and the fractions analysed by spectroscopic methods. The rheological properties of the pitches are being studied. The temperature susceptibilities of normal and modified pitches are also being measured by rheological methods.

The polymerization of styrene and the copolymerization of styrene, indene, and coumarone in coal-tar naphthas at high pressures and temperatures has been investigated, and it has been demonstrated that by this procedure resins of light colour and high melting point may be prepared.

A method for the routine determination of the different classes of insoluble material in tars and pitches has been devised, and a continuous solvent extraction apparatus has been assembled for the preparation of larger quantities of these substances. The insoluble constituents are believed to play an important part in determining the characteristics of the parent tar and it is possible, particularly in the case of low temperature tars, that the structure of the insolubles is related to some extent to that of the original coal.

Therefore, attempts are being made, using both physical and chemical methods, to elucidate the structure of this insoluble material.

(*d*) *Coal Preparation Investigations.*—During the year the programme in coal preparation has been closely allied to the carbonization work, emphasis being placed on the preparation of coal for metallurgical coke production.

In this connexion the study of the washability characteristics of Australian coking coals has been continued, full-scale tests being carried out on the Young Wallsend seam (Stockton Borehole Colliery) and the Victorian Tunnel seam (Burwood Colliery), coals which are of particular importance and interest to the steel making industry. Samples of coal from the Borehole seam (West Wallsend Extended Colliery) and the Victoria Tunnel seam (Waratah Colliery) have also been tested. In carrying out the tests, the distribution of ash, sulphur, and phosphorus has been studied and also the distribution of the main petrographic constituents, which is of particular importance for the preparation of coal for carbonization purposes. The washability test on the Victorian Tunnel seam (Burwood Colliery) was augmented by investigations designed to indicate the degree of liberation of the petrographic constituents which could be effected by crushing.

On the basis of information obtained from washability studies, samples of various coals have been suitably prepared for carbonization tests. Samples of coal from the Bulli seam, Wongawilli seam, Young Wallsend seam, and Victoria Tunnel seam have been washed to give clean coals of the desired ash content by separating high ash material at the necessary specific gravity. This is in contrast to the more usual procedure of cleaning carbonization samples at the arbitrarily chosen specific gravity of 1.60.

Great difficulty is experienced in practice in cleaning coals below ¼-in., particularly with coals having the ash distribution characteristics found in Australian coals. Particular attention is being given to this problem and a hydrocyclone concentrator has recently been constructed specifically for this work. A magnetite suspension is being used as the separating medium, and tests indicate that exact separations of — ¼ in. + 30 B.S. mesh raw coal can be achieved at any desired specific gravity. The capacity of the plant is about 1,000 lb. per hr. The plant augments considerably the facilities for preparing samples of coal of any desired ash content for carbonization and other purposes. The operation of the cyclone and the principle on which it works are being further investigated.

For investigations along similar lines a small-scale continuous froth flotation unit has also been completed. This is now being used principally for fundamental investigations into the rate of flotation of coal and for studying flotation variables such as reagent concentration, feed rate, pulp density, and effect of slimes.

Also in connexion with flotation, experiments have been conducted to determine the extent of adsorption and rate of adsorption of flotation reagents on coal. Preliminary experiments show that cresols are quickly removed from solution by coal, and in consequence a prolonged conditioning time could adversely affect recovery on a flotation plant. Difficulty has been experienced in accurately determining reagent concentrations, and on this account the work has temporarily been suspended pending the installation of additional apparatus.

5. MICROSTRUCTURE OF BROWN COAL.

(Pollen Research Unit.)

The work of the Pollen Research Unit, at the Botany School, University of Melbourne, has been largely concerned with the pollen and phyto-plankton contents of Jurassic, Cretaceous, and Tertiary formations in Victoria, South Australia, Western Australia, Queensland, and New Guinea. In the course of this work remanie microspores of Palaeozoic age have been found in Cretaceous and Lower Tertiary formations.

The trend towards economic application of pollen studies has been greatly intensified. Knowledge of fossil pollen microfloras has advanced to the stage where it permits determination of the stratigraphic age of the pollen-bearing strata encountered in drill cores and outcrops. As a result, during 1955-56 several of the major oil companies and State geological surveys have sought and received help in determining the stratigraphic age of strata intersected in their drill-holes, namely—

West Australian Petroleum Company—a correlation between Rough Range and Cape Range Jurassic deposits;
Australasian Petroleum Company—age of samples of thin coal seams from New Guinea;
Frome-Broken Hill Ltd.—calls from Darriman No. 1 bore, Victoria, and from Queensland;
Department of Mines, South Australia—various bore cores;
Mines Department, Victoria—bore cores from Alberton West Geological Survey of Queensland.

Material has also been submitted by the South Australian Museum and the National Museum of Victoria.

In addition, a study is in progress of the detailed distribution of pollen types in the Latrobe Valley brown coal seams, with the object of determining the cause of their banded structure.

6. UTILIZATION OF LOW-RANK COAL.

(Division of Industrial Chemistry.)

(*a*) *Formation of Methane during Pressure Gasification.*—One of the important features of the pressure gasification process is the ability to produce a fuel gas rich in methane. A study is being made of the reactions which occur when brown coal and brown coal char are contacted with hydrogen-carbon monoxide mixtures under controlled conditions of temperature and pressure, to enable the important methane-forming reactions to be identified and their kinetic features determined. The experimental reactor is of the continuously operated fluidized bed type, designed to operate at a wide range of temperatures and pressures up to 50 atm. The fluidized bed reaction system was chosen in order to control closely the reaction conditions and thus to facilitate the interpretation of experimental results.

The experimental runs completed so far have shown that the hydrogenation of the carbon content of reactive brown coal chars occurs rapidly at temperatures of about 750° C. and pressures of 20-30 atm. The thermally unstable components of brown coal are also readily hydrogenated under these conditions, but much of the reacting hydrogen combines with the oxygen content of the coal to produce water. Very little methane appears to be formed by reaction between hydrogen and carbon monoxide.

(*b*) *Steam-carbon Reaction at High Pressures.*—Although many previous workers have investigated the kinetic features of the steam-carbon reaction with steam partial pressures of one atmosphere or less, very little work has been done at higher pressures and predictions of the possible rate of the reaction under pressure gasification conditions vary widely. In the present investigation precise studies at steam partial pressures up to 40 atm. have yielded sufficient results to indicate that the reaction is described by a rate equation exhibiting the fractional order with respect to steam and the retarding effect of hydrogen which are characteristic of the reaction at low pressure.

(*c*) *Structure of Carbon and its Influence on Gasification Reactions.*—Work has commenced on the study of the gasification behaviour of a series of special carbons, the chemical structures of which have been established by officers of the Physical Chemistry Section. Initially, the reaction of these carbons with oxygen and carbon xide at low temperatures will be investigated. It is ed that this work will help to elucidate the nature and ction of the surface complexes which play an im- tant part in the mechanisms of the oxidation reactions which carbon is gasified.

tudies of the fine pore structure of brown coal chars, ıg the high-pressure mercury penetration apparatus, e been continued.

d) *Analytical Investigations.*—In an attempt to reduce time and effort expended in the analysis of multi- nponent gas mixtures arising from gasification experi- ıts, a thorough study has been made of the gas omatography technique. Very little success has, how- r, been achieved in the analysis of anything except ple two- or three-component gas mixtures. Despite a siderable number of experiments aimed at improving selectivity of the chromatographic column, it has not n possible to achieve adequate separation of the minor nponents in normal fuel gas mixtures containing many nponents such as carbon dioxide, carbon monoxide, gen, hydrogen, nitrogen, unsaturated light hydro- oons, methane, and ethane. Further work has been oended.

Vork has continued on the direct method for the deter- ation of oxygen in coals, particular attention being n to the solution of difficulties which have arisen in application of the method to high-sulphur brown coals.

n conjunction with the Mathematical Statistics Section, urther large number of recorded analyses of brown l samples have been examined statistically, with the aim developing a satisfactory method of conversion of mate analyses to the pure coal basis.

XXI. PHYSICAL METALLURGY.

1. GENERAL.

programme of research on special projects in the l of metallurgy is undertaken at the Section of Physical tallurgy established in the Research School of Metal- y at the University of Melbourne. This work is cribed below. Work on metal physics is in progress hin the Division of Tribophysics (*see* Chapter XXII.). work of the Division of Industrial Chemistry on ndry sands is reported in Chapter XVIII., Section 4.

ection of Physical Metallurgy.—In April, 1956, fessor J. Neill Greenwood relinquished his position as cer-in-charge. He was succeeded by Professor H. W. rner who had been an officer of the Section until uary, 1956, when he was appointed to the Chair of tallurgy in the University of Melbourne.

he Section has continued the researches described in previous Annual Report.

s in previous years, members of the Section have ticipated in the supervision of post-graduate students have answered numerous inquiries submitted by ustry.

Ir. R. C. Gifkins has served as chairman of the cutive committee responsible for the publication of the "Journal of the Australian Institute of Metals".

ate in 1955 Professor Greenwood returned from visits universities and research organizations in the United gdom and Europe. At the same time Dr. H. W. rner returned after making visits in the United States Canada as an officer seconded to the Mines Branch Canada.

2. TITANIUM AND ITS ALLOYS.

(Section of Physical Metallurgy.)

a) *Alloys.*—With the Section's previous work on gle-phase α– and β–solution alloys as a background, ention was directed to the strength at high temperatures titanium-niobium alloys which are mixtures of α– and β–solutions. These alloys were not markedly stronger at elevated temperatures than is pure titanium, but the addition of aluminium, which dissolves preferentially in the α–phase, caused a significant increase in strength at temperatures up to 500° C. Attempts to improve the properties of the titanium-niobium-aluminium alloys by heat treatment were commenced.

Measurements at elevated temperatures of the internal friction and rigidity modulus of pure titanium and its alloys with aluminium, oxygen, and nitrogen were used to examine a phenomenon thought to be strain-aging. Additional indications of strain aging were obtained and the activation energy for the process was determined.

(*b*) *Reactions with Oxygen.*—The effects of alloying elements on the oxidation of titanium were further examined. When oxidation was retarded as occurred, for example, if the alloying element was tungsten, the ratio of oxygen in the residual metal to oxygen in the oxide scale was greater than that found in oxidized samples containing tin or iron which accelerated the oxidation. Any reduction in the total oxidation rate was attended by a high oxygen content in the metal. Titanium-tin alloys, which suffered rapid oxidation, were found to have a low oxygen content in the remaining metal, and they were coated with a scale which could be easily removed.

In all oxidized titanium alloys the layer of alloy adjacent to the oxide scale was found to be enriched in the alloying element.

3. DEFORMATION.

(Section of Physical Metallurgy.)

Continued study of the recrystallization of lead during creep has been made, particularly of the influence of such factors as those listed in the previous Reports. Recrystallization during creep occurs more readily the lower the oxygen content, the shorter the anneal, and the lower the temperature of annealing; conditions may lead either to true recrystallization or grain growth. In commercial lead, accidental variations of these factors locally could lead to exaggerated grain growth and thus contribute to cracking. In order to further study the effects of impurities, a zone-refining apparatus has been constructed to obtain very pure lead.

A suggested mechanism for intercrystalline cracking of brass is being tested by a study of the distribution of slip lines within specimens.

The investigation of the slow deformation of titanium at elevated temperatures has been concluded, and in addition to the results reported previously, information on the strain-aging of titanium at 400-500° C. has been obtained.

XXII. TRIBOPHYSICS.

1. GENERAL.

The Division of Tribophysics has developed from the former Lubricants and Bearings Section established during the war to assure Australian engineering industry of essential information in the manufacture of bearings for aero and other engines. The original investigations have been continued and extended to include fundamental studies in metal physics and the surface physics and chemistry of solids. Major advances have been made in the knowledge of distortions in metals produced by plastic deformation and of topology and reactivity of metal surfaces.

Division of Tribophysics.—The work of the Division has been continued along the general lines described in the last Annual Report.

As in previous years, the Division has co-operated with the Chemistry, Metallurgy, Mining, Physics, and Engineering Departments of the University of Melbourne and is indebted to these Departments for the use of many facilities. An officer has been seconded to the Chemistry Department to work on problems of the solid state.

Advice and assistance have been given frequently to numerous industrial firms, government organizations, departments of various universities, and other Divisions of the Organization. The range of subjects—lubrication, bearings and bearing metals, wear, metals technology, electrolytic polishing, electronics, surface chemistry—illustrates the way in which the fundamental investigations of the Division are related to practical applications. The review of electrolytic polishing methods used in research and industry, several editions of which had been distributed in a mimeographed form, has been revised and published as a monograph.

Officers of the Division have continued to act on various committees, in particular, the C.S.I.R.O.—Department of Supply Engineering Group Committee, the Lubrication Committee of the Department of Supply, and the Committee on Viscosity of the Standards Association of Australia. The metallurgical colloquia held with other metallurgical groups continue to be an important medium for the exchange of specialized knowledge.

The Chief accepted an invitation by Harvard University, Cambridge, Mass., to give a post-graduate course on plastic deformation of metals during the spring term, 1956.

2. PROPERTIES OF SURFACES.

(Division of Tribophysics.)

Apart from investigations on some practical aspects of friction and lubrication, the work on the physics and chemistry of solid surfaces is concerned mainly with the behaviour of molecules adsorbed on solids, the topography of surfaces of metal crystals, and with the catalytic action of these surfaces.

(*a*) *Adsorption from Aqueous Solutions.*—(i) *The Effect of Concentration.*—The studies of the adsorption of long-chain polar compounds on to solid surfaces has been extended to include the adsorption of some of the water-soluble compounds, i.e. the detergents. The wetting behaviour of detergent solutions depends upon the nature of the solid and the concentration of the solution. It has been shown that where a single molecular layer is adsorbed from dilute solutions, in general, two molecular layers are adsorbed from more concentrated solutions. Thus, if the solid surface is hydrophobic to a dilute solution, it may be wetted by a more concentrated one. The clean surface of a metal such as platinum does not discriminate between types of detergents, but non-metallic surfaces such as glass and mica behave differently in solutions of anionic and cationic compounds.

(ii) *The Effect of Crystal Orientation.*—There is indirect evidence from studies of crystal growth that ions or molecules in solution may be adsorbed preferentially on certain faces of a crystal. To gain more direct information the amounts of a simple surface-active ion, viz., dodecyl sulphate, adsorbed on barium sulphate crystals exposing different crystal faces, are being measured. Since large surface areas are required for accurate measurement, powders consisting of uniformly shaped crystals a few microns in size must be used. A study has been made, therefore, of the conditions of nucleation and growth for the preparation of microcrystals with different habits, the orientations being determined by optical methods under the microscope. Two extreme forms are being prepared; the adsorption of dodecyl sulphate on these will be compared with their specific areas determined by gas adsorption and other methods.

(*b*) *Topography.*—In interpreting the results of experiments on the catalytic activity of silver crystals, it is important to know as much as possible about the structure of the exposed surface of the catalyst. Silver crystals have
been treated in several ways, and the surfaces so produ
have been examined to determine their suitability
catalytic experiments. Electropolishing can produc
very flat surface, but it is always contaminated
deposits from the solutions. It has been found that s
surfaces can be cleaned by sputtering, a process wh
retains the surface flatness and leaves no contaminatio

In addition, the nature of surfaces of silver specim
polished by modern metallographic techniques is be
investigated by electron diffraction. Contrary to gen
belief, surfaces which are relatively free from he
deformation can be prepared by mechanical polishing.
no case has a Beilby layer been detected on these
polished surfaces.

(*c*) *Thermal Etching of Silver.*—When silver is he
in air to nearly its melting point certain crystal facets
developed on the surface. The orientations of more t
100 crystals have been measured and the type of ther
etching observed on them after heating in air at 900
has been recorded. It has been found that if the speci
surface is within about 34° of the (111) plane then
etched surface is made up of a mixture of (111) fa
and a randomly oriented plane. Similarly, if the speci
is within about 25° of the (100) plane then a mixtur
facets of the (100) plane and a randomly oriented pl
is produced. Analyses of these results have shown
the sum of the angles which the specimen surface ma
with the low-index etched plane and the random pl
is closely related to the ratio of the surface energy
the low-index plane to the surface energy of the ran
plane. From measurements from microphotographs
the etched crystals the ratio of the surface energy
$(11\bar{1})$ plane to the surface energy of a (100) plan
shown to be approximately 1.1:1. This value agrees
others quoted in the literature.

Further consideration of the role played by the sur
energy of various crystal planes has explained many
the curious phenomena encountered in thermal etchin

(*d*) *Catalysis on Single Crystals of Silver.*—The z
order vapour phase decomposition of formic acid has b
used as a test reaction to show variations in the catal
activity of surfaces of silver crystals of different orie
tions prepared by electrolytic polishing and sputtering
by thermal etching.

The surfaces of the single crystals investigated in
vious work were not atomically flat and probably expo
facets of more than one type. It was assumed that
variety of activation energies obtained from these surfa
was probably effected by a mixture of facets, which w
predominantly of the 111 type for crystal faces close
the 111 orientation and which gave low activation energ

Surfaces which were cleaned by sputtering after elec
lytic polishing gave activation energies which were alm
independent of the bulk orientation of the crystals. H
ever, the rate of reaction seems to depend considera
on the orientation.

The same crystals, when thermally etched, gave a hig
rate of reaction and a lower energy of activation wh
was dependent on the orientation.

It seems, therefore, that a direct relationship ex
between the activation energy and the facets produ
on the surfaces, since an increase in surface area alo
due to etching, would lead only to an increased rate
reaction but not to a simultaneous decrease in activat
energy.

3. METAL PHYSICS.

(Division of Tribophysics.)

The aim of the work is to obtain a better understand
of the plastic properties of metals and of the mechani
of phase changes. This knowledge will make it possi
to state the best conditions of a material for use in pract
and to widen the range of materials available to indust

a) *Plastic Deformation.*—The strength of metals and ys depends entirely on the type, number, and distribu- ı of imperfections (dislocations, vacant lattice sites, king faults, and interstitial atoms) in the metal crystals. ne of these imperfections are present in the undeformed tal, others are produced during the deformation, and y affect the properties in various ways. Their presence ises a small proportion of the energy expended in ormation to be stored in the metal, and this energy released when the metal is heated. Some details of various imperfections and the role which they play in stic deformation may be determined by measuring the ount of energy stored and the manner of its release, d relating such measurements to those of the electrical sistivity, hardness, macroscopic density, and the dis- bution of intensity in X-ray diffraction patterns from formed metals.

(i) *Nickel of Commercial Purity.*—The differential ethod for the determination of small changes in density, entioned in last year's Report, has been used to measure changes in density which occur on annealing deformed ckel. In nickel of commercial purity the decrease in nsity resulting from plastic deformation is not elimi- ted uniformly as the annealing temperature is raised, t two sudden increments in density are superimposed a gradual increase in density. This behaviour is the me irrespective of type (torsion or compression) and tent of deformation.

As discussed in previous Reports, the release of stored ergy from deformed nickel takes place in three stages. e first has been attributed to the disappearance of cancies, the second to various recovery processes, and third to recrystallization. The first sudden increment density occurs in the same range of temperature as first stage in the release of energy, and supports the ggestion that this release of energy is associated with disappearance of vacancies. The second sudden crement in density occurs in the same range of tempera- re as the third stage in the release of energy. Recrystal- ation removes the dislocations generated by plastic formation, and the measurements of density suggest at these dislocations are responsible for a considerable rtion of the decrement in density resulting from plastic ain. Calculations of the density of dislocations from measurements of density and from the measurements stored energy give results that differ by a factor of ten; is is of considerable interest.

(ii) *Pure Nickel.*—Further experiments using a purer ade of nickel have shown that it may be easier to parate the contribution due to vacancies from that due dislocations in this material. The release of stored ergy due to recovery which has been observed for pure copper and nickel, but not for pure copper, has w been found to be absent for this purer nickel also. us observations of the changes in properties due to disappearance of vacancies at relatively low tempera- res are not complicated by the simultaneous occurrence recovery. A correlation of measurements of stored ergy with those of electrical resistivity and macroscopic nsity is therefore being made for this material.

(iii) *Copper.*—The changes in properties due to the sappearance of dislocations during recrystallization are ing studied for pure copper in which neither recovery r the disappearance of vacancies is observed, and the terpretation should therefore be relatively straight- rward.

One factor which has been largely overlooked in the udy of stored energy, and indeed in the consideration of e deformation of metals in general, is that of grain size. ure copper specimens of widely differing grain size but aving the same thermal history are now being studied. he deformations applied prior to the final annealing eatment differ in extent but not in kind, and the type deformation is such that no preferred orientation occurs. Both the mechanical properties and the energy stored during the deformation are being determined for this series of specimens.

(iv) *Arsenical Copper.*—The process of recovery is being studied in some detail in arsenical copper for which an apparent anomaly has been found in measurements of the electrical resistivity during recovery. Observations of the behaviour of single crystals in tensile tests indicate that this anomaly is associated with the formation of " atmospheres " of solute atoms around dislocations and the occurrence of " yield points ".

(v) *Alpha Brass.*—Another type of defect which may be present in the crystal structure of metals is the stacking fault. Such defects are known to occur in the alpha brass and for this reason measurements of stored energy and the various other properties are being made of this material. A further point of interest is the occurrence of short-range order in this alloy, its destruction during deformation, and reappearance during annealing.

(vi) *Fatigue of Nickel.*—Recently consideration has been given to the possibility that the condensation of vacancies created during plastic deformation is the operative mechanism in the initiation of a fatigue crack. However, preliminary measurements of the energy stored in fatigued nickel indicate that the concentration of vacancies is probably less than that present in nickel deformed by unidirectional strain.

(vii) *Nickel Deformed in Filing.*—As mentioned in previous Reports, the energy stored in filings is released on heating in a somewhat similar manner to that for solid specimens. The measurements indicate that a wide range of deformations is present in the filings and that both the maximum and average deformations are considerably greater than those present in heavily deformed specimens of nickel.

The analyses of the X-ray diffraction pattern obtained from filings indicate that a deformed metal contains regions of high strain and regions of comparatively low strain and that on annealing the relief of strain occurs in two stages. During the first stage there is no change in crystal size but a decrease in strain in the low-strain regions without appreciable change in the heavily strained regions. In the second stage the remaining strain is relieved and is accompanied by an increase in " crystal size ".

The measurement of stored energy, together with the analysis of the line profiles, indicates that the first stage corresponds to recovery and the second to recrystallization.

(*b*) *Phase Changes.*—The hardening of steels and light alloys during heat treatment is due to the occurrence of various types of phase changes.

Theoretical work on the crystallography of these phase changes has continued during the year; the rate of its progress was determined largely by the extensive numerical work involved. The comparison of the theory for transformations from body-centred cubic to hexagonal close-packed structures with all the existing experimental data is now complete.

So that observations of the surface relief effects which accompany phase changes may be analysed rationally, a development of the classical method of reducing experimental observations by least squares has been carried out.

XXIII. NATIONAL STANDARDS LABORATORY.

The statutory function of maintaining the Commonwealth standards of measurement is carried out at the National Standards Laboratory by the Divisions of Metrology, Physics, and Electrotechnology.

The National Standards Laboratory maintains close liaison with other similar national institutions overseas and with the International Bureau of Weights and Measures. By its dissemination of calibrated standards and its advisory functions the Laboratory provides an essential service in regard to precision measurement which is of vital importance in many industrial, technological, and scientific fields.

Relations with standardizing laboratories abroad have been strengthened both by research workers from overseas coming to work for a time at the Laboratory and by the latter's staff being able to accept invitations to work for periods overseas.

During the year there has been an increase in the Laboratory's industrial programmes in various fields, particularly in the field of production engineering.

Some alleviation of the problem of shortage of laboratory space has resulted from conversion of an area originally intended as an acoustics laboratory.

Details of the work of the Divisions of Metrology, Physics, and Electrotechnology are given in Chapters XXIV., XXV., and XXVI. respectively.

XXIV. METROLOGY.

1. General.

To ensure complete interchangeability and uniformity of quality and performance in modern engineering production, industry must be able to make accurate measurements. Equipment for this purpose must be regularly calibrated against appropriate working standards. These in turn require periodical calibration in terms of the national standards, certain of which are maintained by the Division of Metrology.

Division of Metrology.—The Division has continued to develop improved techniques for the measurement of the Commonwealth Standards of length, mass, time interval, and associated physical quantities.

Significant contributions are being made to international collaboration through the Bureau International des Poids et Mesures in Paris; the National Physical Laboratory, Teddington; National Research Council, Ottawa; National Bureau of Standards, Washington; and the Physikalische Technische Bundesanstalt, Brunswick. Research in interferometry and wavelength determinations was extended by a gift of mercury and krypton isotopes from the National Research Council, Ottawa.

The Division has also been very active in engineering metrology, vibration, and materials testing fields. The Division has continued to ensure the adoption of sound metrology principles in industry by making staff freely available for advice and assistance, and also by providing a calibration service for balances, weights, volumetric glassware, time pieces, and all types of measuring instruments and machine tools.

The Division has extended its co-operative research programme with industry. Additional laboratory accommodation has been acquired to facilitate production engineering research.

The Division's efforts for the dissemination throughout industry of the principles of engineering metrology, engineering design analysis, and materials machining, are being rewarded by an increasing awareness of the advantages resulting from their adoption.

The staff has continued to co-operate with other Divisions and Government Departments, and also to act on S.A.A., N.A.T.A., C.S.I.R.O./Department of Supply Engineering Group, and other technical committees.

2. Length and Associated Quantities.

(Division of Metrology.)

(*a*) *Standards*.—The regular programme for the maintenance of the national standards of length was supplemented by fundamental research on standardization of length by light waves. Research on isotopic light sources was intensified in accordance with the resolutions of the Tenth General Conference of the Bureau International des Poids et Mesures in 1954.

(i) *Line Standards*.—Intercomparisons were made between the Division's reference standards and working standards, with the use of the universal line standard comparator. Observational technique was of a very high order and results revealed that one of the standards may be unstable. Temperature measurements were made using resistance thermometers and a Mueller bridge, with an estimated accuracy of 0.005° C. Several determinations of the thermal coefficients of linear expansion of various line standards and sample lengths of invar tape were made with the universal line standard comparator.

(ii) *End Standards*.—Maintenance of the reference and working end standards continued. Reference end standards, comprising slip gauges and end bars, up to and including 12 inches, are now being calibrated by interferometry.

A new instrument, designed and constructed in the Division, enables the flatness and squareness of the faces of end bars to be quickly and accurately measured by interferometry.

(iii) *Surveying Tapes*.—Several of the reference tapes were calibrated on the geodetic base. All appeared to have changed in length since their last calibration (at the National Physical Laboratory (N.P.L.)) by a small but significant amount.

Recalibration of three of the reference tapes at N.P.L. revealed no change in length, the apparent change being due possibly to the instability mentioned in item (i).

At present the highest accuracy of measurement of surveying tapes with the geodetic base is from two to three parts in 10^6. A significant improvement, to one part in 10^6, could be achieved from a more precise calibration of the 4-m. standard. To permit this a 4-m. line standard comparator was designed in the Division and construction has commenced.

Tapes have been calibrated for the Snowy Mountains Hydro-electric Authority, the Department of the Navy, the Technical Committee of the XVIth Olympiad, and other bodies. In some cases thermal coefficients of expansion were obtained by heating the tape with A.C. current and measuring the temperature by thermocouples.

At the request of the National Mapping Council the Division has drawn up a proposal, with designs, for equipment to be set up in each State for the calibration of working tapes by the States' Departments of Lands.

(iv) *Kösters-N.S.L. Interferometer*.—A paper describing the performance of this interferometer, designed and made at N.S.L. for the measurement of end standards up to 500 mm. in length, was submitted for publication.

(v) *Light Sources*.—A standard Michelson cadmium lamp containing natural cadmium was made for use as a reference standard for studying the wavelengths emitted from isotopic sources, in accordance with international agreement. Hollow cathode lamps made by the Division of Industrial Chemistry are being studied as interferometry sources. Research on light sources was greatly facilitated by a gift of isotopes, mercury and kryton, from the National Research Council, Ottawa.

(vi) *Wavelength Standards*.—Accessory equipment for a variable-gap Fabry-Pérot interferometer was constructed and precise wavelength measurements will be made shortly. Electrical methods of controlling the movement of interferometric plates were introduced and preliminary tests show great promise. The wavelength data and correction tables mentioned in previous Reports have been published as a N.S.L. Technical Report.

(vii) *Twenty-four Metre Interferometer*.—The project to establish a 24-metre base by Fabry-Pérot interferometry and optical multiplication was recommenced. A trial rangement is being assembled to test the effect of bration in the geodetic base, where the 24-metre base ll be installed.

(viii) *One-metre Interferometer.*—This interferometer, signed to establish a metre directly by interferometry, still under construction.

(ix) *Multiple-beam Interference Comparator.*—This mparator, which will allow the intercomparison of end andards up to 1 metre in length by multiple-beam terferometry, is being modified after test.

(*b*) *General Interferometry Studies and Associated search.*—Studies in multiple-beam interferometry, interrence microscopy, and other optical problems continued. ese include research on phase change at reflection, bration measurement, and obliquity effects. Deposition thin films of metals and dielectrics on reflecting surfaces becoming of increasing importance in most projects.

(i) *Phase Change Studies.*—Work is progressing on the pid evaluation of phase change at reflection at metal rfaces of varying finish. To test a theory of phase ange at a rough surface, diffraction gratings of known aveform were used, and good agreement was obtained tween theory and experiment over the visible spectrum. uipment to measure the ratio of specular to total flection at metal surfaces was made, and phase change easurements are being correlated with this ratio.

(ii) *Multiple-beam Interferometry Studies.*—A method studying very small vibratory displacements using the riodic change in field intensity from overlapping mulle-beam fringes was investigated and the theory veloped.

The Heisenberg uncertainty principle has been applied optical interference, and shows the interdependence of rface resolution and depth resolution. The minimum solvable volume that can be determined by multipleam interference for a given set of conditions was callated, and agreed with experiments.

(iii) *Obliquity Effects in Interferometry.*—Obliquity ects with off-centre apertures were analysed and general lutions obtained for all cases of on-centre and offntre apertures. Exact corrections can be applied in terferometric length measurement. Fringe visibility was so investigated.

(iv) *Thin Films.—Deposition control:* Photoelectric ntrol methods are being tested and possible methods of positing quarter-wave layers of various dielectric films e being studied. A photoelectric transmission system being prepared for metal and dielectric film deposition. *Optical properties of films:* Equipment for accurate easurement of the reflectance and transmittance of posited films is being constructed.

Deposition of all types of films for outside organizations as again considerable. Graticules and grids were preared using chromium and aluminium in the double aporation process. Advice on evaporated film problems cluded using a silica layer on metal as a wettable surface d chromium on glass as a non-wetting durable surface. *Abrasion testing of films:* An abrasion tester made by e Department of Defence Production to the Division's sign is being tested over a large range of evaporated ms.

(v) *Photoelectric Setting Microscope.*—Equipment for tting on fringes or ruled lines with high precision as constructed. An electronic detector was made to dicate the setting position on a meter dial. Precision ultiple-beam interferometry tests are in progress.

(*c*) *Engineering Metrology.*—(i) *Measuring and Conltative Service.*—Numerous requests were met from dustry for routine length, angle, straightness, flatness, d surface finish measurement, and for calibration of rious machine tools, measuring instruments, gauges, d similar precision equipment.

Specific projects included aligning the main drive for a large rolling mill and measurements, involving the design and construction of special equipment, on an unbladed turbine rotor for the Navy. Large numbers of productions gauges are being examined for the Department of Defence Production.

(ii) *Gears and Gear-hobbing Equipment.*—Several gears were examined to the maker's specifications and some spiral bevel gear measuring problems studied.

A large hobbing machine and test gear were examined for the Department of Defence Production.

(iii) *Linear and Circular Dividing Engines.*—Several graticules, linear scales on glass, and circular divided drums for laboratory equipment were ruled.

(iv) *Air Gauging.*—The development of a high magnification two-jet pneumatic comparator for calibration of slip gauges is progressing, and calibrations of internal diameters, including the glass manometer tubes for the standard long-range barometer, were undertaken.

(v) *Screw Gauges.*—Two pairs of American Petroleum Institute (A.P.I.) cable drilling tool-joint gauges were measured and results forwarded to the National Bureau of Standards, Washington, for comparison with results obtained on the same gauges by the Bureau. The comparison proved satisfactory, and the Laboratory is now recognized by the A.P.I. as an authorized testing agency for fast-taper (tool-joint) A.P.I. gauges. Recognition for testing slow-taper (casing, drill pipe, and line pipe) gauges up to 8½-in. diameter was obtained in 1948. Equipment was developed to measure the minor diameter of A.P.I. tool-joint ring gauges.

Routine measurement of threaded components and screw gauges of all types has continued.

(vi) *Periodic Errors in Machine Tools.*—Development of electronic equipment for the measurement of periodic errors in machine tools has continued, and encouraging results have been obtained in the application to lathes. Application to gear hobbing machines is being investigated.

(vii) *Photogrammetric Investigations.*—A paper has been prepared on the analysis of asymmetric distortion. Poor definition in photographs obtained with an aerial camera, and several points concerning calibration of survey cameras, were investigated. The National Mapping Council has requested assistance in the preparation of standard definitions for photogrammetric terms.

(viii) *Lapping and Abrasive Investigations.*—By overseas request, further work was undertaken on the production of very thin slip gauges, free from buckling in the unwrung state. An air elutriator has been developed for the grading of fine abrasive powders.

A satisfactory lapping procedure has been developed for producing suitable quantities of irregularly shaped plates, flat and parallel, and on size within 0.0002 inch, and a standard 62.5-mm. Feby-Pérot type etalon was made in chromium plated invar for comparison of light wave standards.

3. Mass and Associated Quantities.

(Division of Metrology.)

Requests for advice continue, ranging from requests for conversion factors from imperial to metric units, to requests for complete equipment specifications. Assistance was also given to various State Weights and Measures Departments.

(*a*) *Standards of Mass.*—The regular programme of maintenance of the working standards of mass has continued. It is apparent that certain plated brass screw knob weights will have to be replaced soon, preferably by integral weights of more suitable material.

An intercomparison has begun of the Laboratory reference standard of mass. The values obtained will be based on the values of four 1-kilogram standards, two of nickel-chromium alloy, and two of stainless steel, which have been compared with the Australian copy No. 44 of the international kilogram.

Several standards of denominations greater than one kilogram made in the Laboratory will be included in the intercomparison.

(*b*) *Density Measurement.*—The Division's standard hydrometers were reverified during the year. The results are most satisfactory, as values agree with those of the National Physical Laboratory, Teddington. Duplicate measurements made at widely different times under varying conditions agree within the limit of reading accuracy of the hydrometers.

(*c*) *Barometric Pressure.*—Suitable designs have been studied for a primary standard barometer for measurements in the range 680-780 mm. As a result, new detailed designs have been prepared of a comparatively simple instrument incorporating an electric pressure control unit developed in the Division, to measure pressures in this range with an accuracy of 0.01 mm.

Associated with this project is the purification of mercury for the filling of the barometer. This apparatus has been slightly modified, but the basic principles remain unchanged. Mercury of high purity has been produced.

(*d*) *Fluid Flow Measurement.*—A technique has been developed using simple equipment for the calibration of liquid flow meters for industry at rates up to 1,000 gallons per hour with an accuracy better than 1 per cent.

4. TIME INTERVAL.

(Division of Metrology.)

Additional equipment has been ordered for rating of time pieces. This includes a cool incubator for measurement of temperature errors of watches, and a high-speed oscillograph for measurement of very short time intervals. An experimental method of checking the rate of time-of-day watches was tried with some success, but it requires further development before becoming a regular technique.

The paper on the Division's new method for the measurement and analysis of geometric errors in watches, mentioned in the previous Annual Report, appeared in the Proceedings of the Fifth International Symposium on Chronometry, published in 1956.

5. APPLIED MECHANICS.

(Division of Metrology.)

The Division co-operated closely with local industry, particularly in mechanical and production engineering. Heavy demands were met for calibration of various materials testing machines used for measuring force, hardness, pressure, and similar physical quantities. Industry is becoming increasingly aware of the importance of vibration isolation in machine tools, and the Division has continued to assist in the solution of vibration problems.

Machining and engineering design analysis research has been intensified and several co-operative projects are in progress.

(*a*) *Machining Research.*—The Division's machining research consists broadly of two parts, the one dimensional and concerned with tolerances and the variability of production processes, and the other mechanical and concerned with tool forces, horse power, tool life, etc. One project, proceeding in collaboration with a Sydney firm, involves the machinability of Australian materials to establish reliable cutting data. Materials machinability depends on metallurgical structure, and the Defence Standards Laboratory, Sydney, is collaborating on this aspect. Preliminary tests revealed concentrated wear in the form of grooves on the clearance and top rake surfaces of the cutting tool at a position corresponding to the periphery of the work. The explanation is given in a paper submitted for publication.

Investigations into the high-speed routing of " Alclad " were intensified. The optimum cutter geometry has now been confirmed and a blade-type cutter developed using replaceable inserts. Provisional patents were applied for to cover both these features, and commercial applications are being investigated. The cutters are operating well under production conditions and performance data are being collected.

A Schlesinger-type abrasion tester was developed for testing the abrasive properties of materials in machining.

A method was developed for cutting germanium for transistors into slices 0.01 in. thick for the Radiophysics Division. An industrial firm collaborated and donated the diamond wheels for the tests.

Several clamped-on type chip breakers for cutting tools were designed and comparative performances investigated.

(*b*) *Engineering Design Analysis.*—A course in engineering design analysis was prepared for University and Technical College lecturers who will teach this subject, and an invitation accepted from Sydney University for an officer to lecture during third term, 1955, to fourth year engineering students on this subject. A paper on the industrial application of limits and fits was read to the Engineering Group of the 1955 A.N.Z.A.A.S. Conference.

Joint experimental investigations with industry into tolerances for production processes have commenced. The first process is the tapping of nuts, a matter of international importance in view of discussions at the 1955 American-British-Canadian Conference at New York. The factors which influence the frequency distributions of both the dimensions of the drilled hole before tapping and of the important elements of the tapped nuts will be investigated. This work was facilitated by taps and a drill sharpening machine loaned by industry and an automatic screw machine from a Government Department.

(*c*) *Vibration.*—(i) *Vibration Isolation.*—Requests continue for advice on the isolation of sensitive instruments and precision machine tools from vibration generated by forging hammers, compressors, and other industrial sources.

The Division collaborated in the design of vibration isolation mountings of 50 tons' load-carrying capacity for a large jig borer, and assisted in designing 120 tons' capacity rubber-in-shear isolators for a roll grinding machine. Performance tests on both machines, including evaluation of critical frequencies, were made. Two general-purpose vibration tables were developed and are undergoing controlled transmissibility tests.

A comprehensive survey of information on vibration isolation and measurement has been published. An officer presented a paper on vibration measurement and isolation to the Institution of Engineers, Australia, in Sydney in July, 1955.

(ii) *Vibration Measurement.*—Many industrial requests necessitated vibration measurements for site selection and mounting evaluation purposes. The electrical-capacity type vibration meter had considerable use and three new improved seismic transducers are being developed. Additional equipment was acquired or developed to facilitate vibration measurement.

Information was obtained about vibration from preliminary operations for foundation pile-driving at the new Sydney University Chemistry Building.

(iii) *Vibrometer Calibration.*—Preliminary work was done on the design of a vibrometer calibrator, but immediate requirements were met with improvised vibration tables.

(*d*) *Dynamic Balancing.*—A simple, direct method of calibrating dynamic balancing machines was developed, using a Divisional technique for plane balancing by the " three-mass " method. This has been submitted for publication.

A survey of Australian facilities for dynamic balancing as made in co-operation with the C.S.I.R.O./Department Supply Engineering Group Committee to meet the many quiries for dynamic balancing services.

(*e*) *Measurement of Physical Quantities.*—(i) *Force.* Additional proving equipment was obtained to extend e range of force measurement. This includes a 1,000-lb. oving ring, a 30-, a 100-, and two 500-ton Amsler boxes, d three Zwick load rings of capacities 30, 100, and 0 kg. Little development work was possible owing to e heavy demands made on staff for calibration of aterials testing machines.

(ii) *Hardness.*—A single-lever Brinell machine acquired r the calibration of hardness test blocks is in service. vestigation of the accuracy of calibration of the Vickers achine microscope resulted in the design of a better stage crometer. Investigations continued on the N.P.L. type ad-load Rockwell hardness testing machine and intermparisons with overseas authorities on Rockwell C scale terminations are being made. Several devices for easuring indenter force in hardness testing machines, inuding proving levers and an electrical-capacity type force nsducer, were investigated. A technique for the more curate measurement of an indenter force of 1 kg. wt. is ing developed.

(iii) *Impact.*—Apparatus was designed to facilitate the ibration of impact testing machines. The new equipent will be more readily transported and operation icker and simpler than at present.

(iv) *Angular Speed.*—Calibration equipment for tachoeters up to 16,000 r.p.m. was developed.

XXV. PHYSICS.

1. General.

The Division of Physics, which is one of the Divisions the National Standards Laboratory, is responsible for intaining the Commonwealth standards of heat, light, cosity, and related fields and for the associated testing l calibration of measuring equipment. The maintenance standards is never a static subject since new requirents are continually coming forward and consequently, carry out its functions, a considerable amount of the vision's effort is devoted to the development of new or proved methods of maintenance of standards and cision measurement.

This Chapter describes the work of the Division of ysics, and the Division's work in solar physics is cribed in Chapter XXIX., Section 2.

Division of Physics.—A highlight of the year's work been the demonstration of the great precision, speed, l adaptability of the new absolute method of measuring midity mentioned in last year's Report.

The dissemination in industry of knowledge of techues and temperature measurement and control has prossed very satisfactorily. In the field of colour measurent and prediction advice has been given to a number branches of industry, and basic theoretical and experintal work on this subject has been commenced. This eing supported financially by an industrial firm.

Researches into the basic structure of metals and alloys deduced from studies of their thermal and electrical perties at very low temperatures have been continued, l quantitative measurements have meen made on crystal perfections produced by cold work. The section on the rmal conductivity of solids at low temperatures in the ently published Encyclopaedia of Physics was conuted by an officer of the Division.

Theoretical and observational studies of solar phenomena e been continued and a new observing station has n established some 30 miles west of Sydney adjacent to ield station of the Division of Radiophysics. Plans in hand to participate in the programme for the Interional Geophysical Year.

The work of the Division has been recognized abroad by invitations to a number of its officers to visit and work at overseas laboratories or to contribute to international conferences. One officer has been appointed to a visiting professorship at the National Research Council of Canada, and has also been invited to contribute to an international conference and to a meeting of the American Institute of Physics. Another officer has been appointed a Research Fellow for a year at Harvard College Observatory, and two others have been awarded short-term Fellowships at the Massachusetts Institute of Technology. The Division was represented by invitation at a meeting of the International Commission of Optics held recently in the United States of America, and an officer has been invited to participate in a symposium on the theory of image formation in optical systems, organized by United States authorities.

The Division has co-operated with the New South Wales Public Works Department on the problem of the measurement of soil density for the Adaminaby Dam.

The Division has representatives on the following committees:—Consultative Committee on Thermometry of the International Bureau of Weights and Measures, the Working Group on Thermometry of the International Organization for Standardization, New South Wales State Committee of the National Association of Testing Authorities, the Registration Advisory Committee for Heat and Temperature Measurement and for Photometry of the same body, the National Standards Commission, the Committee on Viscometry of the Australian Standards Association, the Technical Advisory Committee on Optical Munitions, and the Australian National Committee on Illumination.

2. Heat.

(Division of Physics.)

In heat investigations the main activities are in temperature measurement, viscometry, hygrometry, and low-temperature physics. Although in this Report reference is made only to advances in the facilities, techniques, and researches, assistance is also constantly given to industry and other scientific establishments in the calibration of equipment, the making of measurements, carrying out *ad hoc* investigations, and giving advice on heat problems.

(*a*) *Measurement and Control of Temperature.*—(i) *International Temperature Scale.*—Much effort has been devoted to the maintenance of the International Temperature Scale and improvements in its realization in all its ranges.

At the invitation of the International Bureau of Weights and Measures the Division has participated in an international intercomparison of resistance thermometers.

A precision manometer for the measurement and control of pressures to 0.001 mm. for the realization of the steam and sulphur boiling points is nearing completion. A tin bath, uniform to 0.01° C., has been constructed to replace the freezing point of antimony for the transfer from the resistance thermometer to the thermocouple pyrometer ranges.

To minimize uncertainties in optical pyrometry the visual sensitivity curves of a panel of observers have been directly determined and an alternative method of obtaining the brightness match photoelectrically has been developed.

(ii) *Liquid-in-glass Thermometers.*—Thermometer readings are markedly dependent on the previous thermal history of the thermometers, and procedures have been devised to improve their stability by reducing the effects of ambient temperature and of heating to an elevated temperature.

(iii) *Industrial Pyrometry.*—Over 50 industrial furnaces and salt baths have been tested, and numerous industrial problems in temperature measurement were dealt with. A five-week course of instruction was given to some twenty persons from industrial establishments.

(iv) *Hypothermia.*—The equipment developed for the lowering of the body temperatures in human patients for medical purposes has been applied in co-operation with hospital staff to a number of operative cases. Improved equipment based on the original design will soon be available for routine use in hospitals.

(*b*) *Hygrometry.*—The method of measuring and controlling humidity with a hygrometer which uses as the sensitive element a water soluble ionic crystal has been brought to an advanced stage of development. A detailed investigation of the characteristics of the method has confirmed its many advantages over other methods for a wide variety of applications. An automatic self-balancing unit has been constructed which is sensitive to changes of less than 0.003° C. in the dew point of the gas being examined, is accurate to 0.03° C., and has a speed of response of 1 sec.

Among the investigations made in connexion with the further development of the method are the design of a system of high thermal efficiency for cooling by carbon dioxide expansion, the production of a water vapour pressure constant to 0.02 per cent., and the development of an electrical analogue for the solution of problems of transient heat flow in materials of irregular shape. An examination of the fundamental limitations of the dew point hygrometer has revealed that undetected errors of 0.5° C. may readily occur in its use.

A semi-automatic frost-point hygrometer, intended for industrial measurements on gases of very low moisture content, has been designed.

(*c*) *Viscometry.*—The construction of a new system of viscometric standards which will be more accurate and versatile than the existing ones is proceeding. A critical examination has been made of certain standards specifications for the measurement of viscosities.

From studies of the drainage of liquids from vertical surfaces a simple procedure to reduce drainage errors in volumetric glassware has been formulated.

(*d*) *Soil Density.*—The rapid measurement of soil density is important in engineering rolled earth construction, and an instrument devised to do this in terms of the absorption of gamma rays is now in use at the Adaminaby Dam site.

(*e*) *Low-temperature Physics.* (i) *Low-temperature Facilities.*—The low-temperature research programme has been extended to include measurements on specific heats.

The 15,000-gauss magnet, which is being constructed for use in the production of temperatures below 1° K. and for the study of phenomena in the presence of a magnetic field, is nearing completion.

(ii) *Conduction Phenomena in Solids.*—Work is proceeding on the identification of the dominant types of crystal lattice imperfection and the determination of their concentrations from measurements of thermal conductivities at low temperatures. By comparison with the electrical conductivity, information is obtained about their spatial distribution. This technique has been applied to the study of the imperfections introduced by plastic deformation in arsenical copper, and it has been confirmed that these are mainly dislocations. Measurements on a series of copper-zinc alloys both in the deformed and annealed states reveal that in these materials both dislocations and vacancies are introduced by cold work.

From measurements of the lattice thermal conductivity and electronic conductivities of annealed alloys of copper it has been concluded that there is a strong interaction between the conduction electrons and the transverse lattice waves in these materials, and further evidence has been obtained for the band structure postulated to explain earlier results.

Measurements have been made on the thermal and electrical resistivities of titanium, zirconium, iron, nickel, and chromium. These latter are of particular interest since they are the first measurements on pure chromiu

Further progress has been made on the theory of th electrical conductivity and thermoelectricity of metal under conditions when the lattice waves deviate fro equilibrium.

From an analysis of the low-temperature thermal co ductivity of crystalline quartz irradiated with fast neutro it has been possible to explain the apparently anomalou density changes observed in irradiated quartz.

(iii) *Properties of Superfluid Liquid Helium.*—Wor has been continued on the phenomenological theory heat transport in liquid helium and on an atomic theor of dissipative processes in the superfluid state.

(iv) *Specific Heat.*—Studies on the specific heats metals and alloys at low temperatures can contribute our understanding of the basic structure of these solid Many specific heat measurements at low temperature have been vitiated by experimental errors. These hav largely been overcome by using a vacuum calorimeter which is incorporated a mechanical heat switch, by th use of carbon resistance thermometers, and by the use specimens of known purity and physical state.

Measurements on specimens of chromium, nickel, an on dilute copper alloys showed that their specific heats low temperatures can be adequately represented as th sum of a term due to the free electrons and one due the crystal lattice. The measurements on copper an copper alloys reveal that while the second term is littl affected by impurities in the copper, the first is affecte to a much greater extent than current theory woul predict. The physical state of the specimens has littl effect on either of the component specific heats. Th measurements on pure nickel and chromium have resolve an apparent anomaly in the published results on thes metals.

(v) *Temperature Measurement.*—To facilitate the cal bration of temperature measuring equipment at the boilin point of hydrogen, a small liquid-helium to liqui hydrogen converter has been constructed.

3. LIGHT.

(Division of Physics.)

In addition to the maintenance of photometri standards, the research and development necessary f the continual improvement of these standards, and th provision of facilities for the calibration of precisio photometric and optical equipment, research activitie have been continued in physical optics and solar physic Methods have been developed for handling mult dimensional coherent scattering problems in radiati transfer, contrast transfer functions for the assessme of optical image quality are being further studied, pa ticularly in connexion with partially coherent obje illumination, while the physical conditions in sol prominences and flares have been more closely determine

(*a*) *Photometry.* (i) *Photometric Standards.*—Th basic standards of luminous intensity flux and colo temperature maintained in the Laboratory are filame lamps. Much develomental work has been carried o in the last year on fluorescent lamp standards, an standards of luminous flux have now been established the form of tubular fluorescent lamps. In the cours of this work two problems which have hindered the sati factory development of such standards have been solve Firstly, account has been taken of the effects of ambie temperature on the luminous output of the lamp measuring its internal resistance, this being related to internal vapour pressure which is the significant fact in controlling lamp output. Secondly, the disturbanc introduced by conventional electrical measuring instr ments on the lamp's voltage and current waveforms an their effect on light output and power consumption ha been investigated, and simple methods found for correcti for them to an accuracy of better than 0.1 per cent.

(ii) *Test Work.*—Photometric testing and calibration ias remained at a considerable level, including the calibraion of incandescent and discharge lamps, photometers, ind haemoglobinometers; spectrophotometry and colorinetry; the testing of retroreflectors for traffic authorities; ind the calibration of gloss standards.

(iii) *Assistance to Industry.*—The paper, plastics, and eramics industries have shown increasing interest in the ise of physical methods for controlling the colour and eflectance of their products. The Laboratory has proided assistance by giving technical information, calibratng reference standards, and training industrial personnel n the application of spectrophotometric and other echniques to their problems.

(*b*) *Physical Optics.* (i) *Image Quality—Contrast ransfer Functions.*—The assessment of image quality y the contrast in images of sinusoidal gratings has ecome one of the major fields of development in optics, or it is now realized that conventional test methods based n the resolution of fine detail do not give the best assessnent of the performance of an optical system. The Division is concerned at present with the development of iew techniques for producing monochromatic and white ight object patterns having known sinusoidal contrast ariations and with variable degrees of coherence. The nathematical functions involved in studying defocused mages have been calculated and tabulated and studies iave been made of the combined effects of small aberraions with a partially coherent object pattern.

(ii) *Radiative Transfer.*—The mathematical theory of he passage of radiation through absorbing and scattering nedia is of importance in understanding the properties f things as diverse as stellar atmospheres or the colour roperties of paints and pigments. Known as the theory f radiative transfer, it has been extended for coherent cattering to the stage where most common two- or threelimensional problems can be handled to an accuracy omparable with that obtained by the Eddington approxination in one-dimensional cases.

These methods have been applied to obtain some of he optical properties of imperfectly dispersed pigments.

Experimental work has also been commenced on the ptical properties of diffusing media. This field has been omparatively neglected by optical laboratories, although t is of considerable importance in many industries.

(*c*) *Solar Physics.*—This work is described in Chapter XXIX., Section 2.

XXVI. ELECTROTECHNOLOGY.

1. General.

Much electrical work, particularly in electronics, is ndertaken in Divisions and Sections as an integral part of research in other fields of investigation, but the Organiation's research on electrical measurements and tandards and on electrotechnology is carried out within he Division of Electrotechnology, which is part of the National Standards Laboratory (*see* Chapter XXIII.).

The Organization also collaborates with the Electricity Supply Association of Australia in encouraging electrical esearch within the universities through its Electrical Research Board (*see* Section 8 of this Chapter).

Division of Electrotechnology.—The Division is responible for the maintenance of the Commonwealth standards of measurement of electrical quantities. It also maintains the Commonwealth standard of measurement of requency in conjunction with the Commonwealth Obserratory, Mt. Stromlo, and other standards derived from requency, resistance, and electromotive force. The Division undertakes electrical and magnetic measurements n materials, and the calibration of instruments and equipment such as resistors, bridges, potentiometers, capacitors, inductors, indicating instruments, instrument transformers, signal generators, wavemeters, and fluxmeters. Research is being continued to improve and extend the electrical measuring and standards facilities, and on the dielectric properties of insulating materials and the microwave spectra of gases.

Investigations requiring the design and development of special equipment have been undertaken for the Enterprise Exploration Co. Pty. Ltd., the Commonwealth Bureau of Mineral Resources, and the Division of Fisheries and Oceanography.

2. Direct Current.

(Division of Electrotechnology.)

The volume of standards and measurements work at direct current has now increased to such an extent that the Division is forced to restrict its service mainly to the calibration of precision equipment for other laboratories and to divert items such as indicating instruments to other laboratories approved by the National Association of Testing Authorities.

3. Power Frequency.

(Division of Electrotechnology.)

For a number of years the precise measurement of voltage at power frequencies and, indirectly, of current has been carried out by means of an electrostatic voltmeter which has proved well fitted to the task. Its favorable properties have now been embodied in a new instrument possessing a number of additional useful features. Instead of observing the deflection of the instrument by means of the usual lamp-and-scale optical system, the deflection of the new instrument modifies the balance of a capacitance bridge of which the electrostatic voltmeter forms one arm. The balance of the bridge is restored by adjusting a variable air capacitor scaled in volts. Since no direct observations need be made on the voltmeter movement itself, the instrument is easy to mount.

Measuring facilities at higher voltages have been improved by the construction of a recurrent surge oscillograph for investigating the voltage distribution on transformer windings under impulse conditions.

4. Audio and Radio Frequency.

(Division of Electrotechnology.)

(*a*) *Calculable Capacitor and Absolute Determination of the Ohm.*—A major research effort has been concentrated on the development of a capacitor whose value may be calculated from its dimensions and on the measuring techniques required to measure its capacitance in terms of frequency and the 1-ohm standard of resistance. If sufficient precision can be obtained, then it becomes an alternative method for the absolute determination of the ohm, using the value of the velocity of light to convert the capacitance, calculated in electrostatic units, into electromagnetic units.

One of the most significant advances has been the discovery of an entirely new form of capacitor consisting of a symmetrical arrangement of straight bars. With this arrangement the mechanical and metrological requirements are notably less stringent than for earlier designs. Almost its only drawback is its low capacitance for its size, and it is likely that the calculable standard will have a capacitance of less than one picofarad. It is fortunate that in recent years the Division has specialized in the precise measurement of small capacitors and that existing techniques can be refined for measuring such a small capacitor.

Less spectacular but equally necessary progress has been made in the other measuring links required to complete the chain back to the 1-ohm standard of resistance. Advantage has been taken of modern electronic techniques and components in the development of special ratio transformers, detector-amplifiers, and cathode-ray display units for A.C. bridges so that measurements of capacitance and resistance may be made with the maximum possible precision. With a new method of display the bridge balance is achieved with much less time and skill than that normally required, because the out-of-balance condition is graphically indicated.

(*b*) *Capacitor Transducers.*—The successful development of equipment for measuring very small capacitors accurately and easily enables capacitor transducer techniques to be used for mechanical and physical measurements. In collaboration with other Divisions of the National Standards Laboratory these techniques have been applied to a barometer, a manometer, and a liquid helium depth gauge. To demonstrate the potentialities of the technique an exhibit was arranged which showed the deflection of a large steel joist under light finger pressure.

(*c*) *Conductance Standard for Very High Frequencies.*—Assistance has been given to the Divisions of Plant Industry and of Food Preservation and Transport in measuring the A.C. impedance of plant tissue. This has been of value in research on the infections of potatoes by virus and on the physical properties of plant cells. The Department of Agriculture of the University of Sydney has been given advice on measuring conductivity by an A.C. bridge. This technique is of interest for determining the amount of calcium in milk.

(*d*) *Frequency Measurement.*—Newly acquired apparatus now permits the measurement of frequencies up to 100 Mc/s. with ease and precision. These measuring facilities are being extended to cover the television and higher frequencies.

(*e*) *Conductance Standard for Very High Frequencies.*—The greater use of very high frequencies for services such as television and navigational aids has created a demand for the corresponding basic standards of measurement. One of the most important quantities to be measured is the impedance of the various transmission circuits and components. Several commercial impedance measuring equipments are available and regular requests for their standardization are being received. At these frequencies it is no longer possible to derive precise impedance standards from the 1-ohm resistors maintained at direct current, and such standards must be based on the known properties of coaxial lines made with sufficient mechanical precision and from metals with adequate conductivity. Standards of this type are under development.

(*f*) *Power Measurement at High Frequencies.*—Bolometric methods of power measurement for the microwatt and milliwatt ranges are being developed. The immediate application for these methods is the direct determination of the power output of standard-signal generators.

(*g*) *Microwave Measuring Equipment.*—Facilities for making accurate measurements at microwave frequencies are being extended as rapidly as funds and available workshop assistance permit. The main effort is being devoted to the 3-cm. waveband together with some work at 10 cm. and 8 mm. A frequency-stabilized klystron oscillator controlled by means of an invar cavity resonator is under development.

(*h*) *Microwave Spectroscopy.*—Hyperfine structure, arising from the quadrupole moment of the deuteron, has been observed in the microwave spectrum of the heavy water molecule. Good resolution of these deuteron quadrupole effects has been achieved with the spectroscope operating under high-resolution conditions, and an attempt is being made to correlate the spectrum with the currently accepted electronic structure of the water molecule.

(*i*) *Random Noise.*—One of the fundamental limitations in any electrical measuring technique occurs when the changes in the desired signal are masked by the background of random electrical variations, that is, by noise arising from the measuring circuits themselves. A programme to study the characteristics of electrical noise generally has been undertaken.

A theoretical investigation of the effects of random voltages in non-linear electrical networks is being carried out, and in particular the problem of finding the probability distribution for the filtered output of a multiplier whose inputs are correlated random voltages, with Gaussian distribution, has been solved.

5. MAGNETIC MEASUREMENTS.

(Division of Electrotechnology.)

A new instrument, greatly facilitating the calibration of fluxmeters and ballistic galvanometers, has been produced. It is a " flux-linkage generator " in which the saturation magnetization of a grain-oriented nickel-iron magnetic core provided with output windings is reversed by reversing the D.C. current in an exciting winding.

Testing facilities have been extended by the addition of a 25-cm. Epstein square for loss and permeability tests on magnetic materials in sheet form and of a fast *X-Y* recorder for plotting characteristics of magnetic materials.

6. DIELECTRIC INVESTIGATIONS.

(Division of Electrotechnology.)

In previous years this work has centred around the dielectric properties of organic compounds in the solid state. Increasing evidence has been obtained that in many cases the magnitude of the dielectric absorption in organic solids is greatly influenced by the presence of crystal imperfections. More attention is now being paid to the dielectric properties of liquids and inorganic solids.

(*a*) *Alkali Halides.*—The dielectric absorption has been studied in several alkali halides containing small amounts of a divalent metal ion of approximately the same size as the alkali cation. In this way quantitative information about the energy barriers to ionic movement in these solids has been obtained without having to grow large crystals. From some points of view this method yields results having less ambiguity than those achieved with the alternative techniques based on diffusion and D.C. conductivity measurements.

(*b*) *Modified Barium Titanate-Type Compounds.*—Compounds of the general formula $Ba_x\ Ti_{8-x}\ Mg_x\ O_{16}$ have been studied. It has been found that they have considerable dielectric absorption at radio frequencies. This absorption is attributed to the transition of barium ions to adjacent unoccupied sites in the crystal structure.

(*c*) *Wool Wax and its Derivatives.*—The investigation of the dielectric properties of wool wax has been extended to a number of easily obtained derivatives, including the acetates of the alcohols, the methyl and ethyl esters of the acids, and also the ketones, secondary alcohols, and hydrocarbons obtained from the acids. The results suggest that some of the materials may have commercial application and arrangements are in hand to impregnate some capacitors with the more promising derivatives.

(*d*) *Wool Wax-Water Mixtures.*—During the above investigation it was realized that mixtures of wool wax and water would provide an excellent example of the simplest form of a heterogeneous dielectric, viz., one containing spherical regions of conducting impurity. Good agreement between experiment and theory was obtained for mixtures containing up to 30 per cent. of water.

(*e*) *Hindered Hydroxy Compounds.*—Previous work on aliphatic long-chain alcohols revealed very large dielectric absorption at audio and radio frequencies. Although the mechanism causing this is obviously due to the hydroxyl groups and their interaction the details are by no means clear. Work was undertaken to establish the dielectric properties associated with a single hydroxyl group sterically hindered from bonding with neighbouring groups. Two compounds, 2:4:6-tri-t-butylphenol and tricyclohexylcarbinol, both showed perfect Debye relaxation type of absorption over a wide temperature range.

(*f*) *Chlorinated Aromatic Compounds as Commercial Dielectrics.*—Appreciable quantities of tri- and tetrachlorobenzenes occur as by-products in the Australian chemical industry. At the request of a chemical manufacturer these by-products were investigated as possible impregnants for capacitors and transformers. It was found that after purification of the compounds the conductivity was still too high. This could be reduced to an acceptable value, however, by mixing with approximately equal quantities of more viscous compounds such as the chlorinated diphenyls.

(*g*) *X-ray Crystallography.*—Dielectric studies suggested the existence of three separate phases of butyl stearate in which the compound remains translucent in appearance. X-ray measurements have confirmed the existence of the three separate phases.

(*h*) *Theoretical.*—In recent years various authors have published conflicting treatments of the dielectric constant. It has now been shown that a proper interpretation of the relevant statistical mechanical averages is of the utmost importance in general theories of the dielectric constant and that several theories apparently in disagreement do in fact state the same result.

Progress in the theory of electron-lattice interaction in metals has been made by the use of electron-hole pairs which have interesting particle properties. Useful results obtained relate to the change of sound velocity induced by the electron-lattice interaction.

7. Special Investigations.

(Division of Electrotechnology.)

(*a*) *Physical Oceanography.*—The two instruments developed for the measurement of temperature and salinity have been completed. One of these, a portable unit for use in estuaries is in regular use, and a number of similar instruments are being assembled by a local manufacturer for the Division of Fisheries and Oceanography, and for export to New Zealand and New Caledonia. The other instrument, a recording instrument for use in the open sea to depths of 3,000 feet, has given encouraging results in its first sea trials, but further slight modifications will be necessary.

The variations in mean sea-level on the east Australian coast are being studied. It has been found that sea-level changes are correlated with atmospheric pressure changes, and with the component of wind parallel to the coast. The study of mean sea-level variations is expected to throw light on the general circulation of the Tasman Sea.

(*b*) *Equipment for Bore Hole Exploration.*—An investigation is being carried out for Enterprise Exploration Company Pty. Ltd. to facilitate measurements of radioactivity in exploratory drill holes. A system is being developed to transmit information to the surface without the difficulties of using an electric cable or special rods. Following laboratory tests on the normal drill rods, equipment is being built for field trials. Pulses from a Geiger-Müller tube in the drill hole are converted into vibrational pulses in the drill rods in which the pulses are propagated to the surface where they may be received by suitable equipment.

(*c*) *Auxiliary Equipment for Shoran.*—Assistance has been given to the Commonwealth Bureau of Mineral Resources in the design and construction of auxiliary equipment for a Shoran radar set. The Shoran is used for navigating and plotting the position of an aircraft engaged on geophysical surveys. An aided layer has been designed and constructed for assisting the radar operator to keep the range signals aligned, and a straight-line flight indicator has been designed. As well as providing a signal for the pilot so that the aircraft may be flown along a series of straight lines, the flight indicator also plots to scale the track of the aircraft.

8. Electrical Research Board.

The general objective of the Electrical Research Board is to foster fundamental electrical research in universities and the training of graduates in research methods. Grants are made for projects suggested by the universities.

The Board is representative of the Electricity Supply Association of Australia, the universities, and the Organization. Financial support from member organizations of the Electricity Supply Association has enabled the Board to support investigations in most of the universities of Australia.

Investigations on the stability of power supply systems are being continued in the University of Adelaide with projects on network analysers and in the University of Melbourne by using model machine techniques. Transients are being studied in the University of Tasmania. In the University of Queensland work has been completed on the construction of the impulse generator and ancillary measuring and recording equipment; substantial progress has been made on thunderstorm studies and the preparation of an isoceraunic map. Work has been continued on electronic counters and amplifiers of extremely short-time resolution and on the Hall effect in semi-conductors in the University of Sydney where a new project on the dynamic stability of alternators has been started. The New South Wales University of Technology has also started a project on the representation of synchronous machines by electronic models. Investigation of the loss of electrode material from hot spots in electric arcs is being continued in the University of New Zealand.

XXVII. RADIOPHYSICS.

1. General.

The techniques of radio and particularly its more recent offshoot, radar, have found employment in an ever widening field of both scientific and industrial application. The use of pulse methods and the exploitation of very much higher frequencies than was possible a decade ago have provided scientists with new research tools of surprising versatility and power. The Division of Radiophysics is organized to carry out investigations in fields in which modern radio techniques have particular application. Chief among these are fundamental researches in cloud and rain physics and radio astronomy—fields in which it has already established an international reputation. The Division is also concerned with the study of physical properties of semi-conductors, and especially the devices known as "transistors" which are initiating a major revolution in electronic techniques; with the development of radio aids to navigation; and with high-speed computation by electronic means.

The Organization's researches on the propagation of radio waves under the direction of the Radio Research Board date back a long way in the history of radio and have contributed much to the understanding of fundamental conditions and processes in the ionosphere. The Board, which was established in 1927, co-ordinates the researches of a group of permanent C.S.I.R.O. officers with allied investigations in the Services, the Postmaster-General's Department, and the universities. It fosters approved projects in the universities where staff and student interest exists. Liaison between the various bodies carrying out research in the radio field and those who make use of the results of this research is facilitated by a Consultative Committee on Radio Research.

The work of the Division of Radiophysics is outlined in Sections 5, 6, and 7 of this Chapter and in Chapter XXVIII., Section 8; Chapter XXIX., Section 3; and Chapter XXX., Section 3. That of the Radio Research Board is described in Section 8 of this Chapter.

Division of Radiophysics.—The Division is predominantly engaged in basic and applied investigations in the field of rain and cloud physics, and fundamental research in radio astronomy. Some effort is being devoted to the study of the physics of semi-conductors, in particular of transistors and their applications in electronic circuitry; and to some aspects of radio navigation and of the propagation of radio waves.

The past year has provided a significant forward step in the Division's rain physics investigations, with the initiation of the first carefully planned field experiment designed to test the efficacy of airborne seeding with silver iodide as a means of increasing rainfall. Highlights in radio astronomy have been outstanding work with the Division's Mills Cross; and further support for the proposed giant radio telescope in the form of a gift of 250,000 dollars from the Rockefeller Foundation of New York, and smaller amounts from donors within Australia. Plans for this instrument have been advanced a further stage with the placing of a design study contract with a leading firm of consulting engineers in England, Messrs. Freeman, Fox & Partners.

The Chief of the Division, Dr. E. G. Bowen, visited the United Kingdom at the beginning of the year to investigate problems connected with the engineering design of the giant radio telescope and to discuss problems of cloud seeding with the British Meteorological Office and Imperial College. He also visited the United States of America by special invitation, to attend a symposium at the University of Arizona on "The Scientific Basis for Weather Modification Studies", and to advise the United States Weather Bureau on its hurricane research project. The opportunity was also taken to discuss radio telescope design studies now being initiated in the United States of America.

The Assistant Chief of the Division, Dr. J. L. Pawsey, as President of the Radio Astronomy Commission of the International Astronomical Union, attended the General Assembly of the International Astronomical Union held in Dublin in August, 1955, and also a symposium on radio astronomy at Jodrell Bank, Manchester, which preceded it. Dr. Pawsey was President of Section A at the meeting of the Australian and New Zealand Association for the Advancement of Science, held at Melbourne in August, 1955.

Mr. J. P. Wild, Senior Research Officer, also attended the International Astronomical Union symposium at Jodrell Bank and General Assembly at Dublin and then proceeded to the United States of America, at the invitation of several radio astronomy research centres anxious to benefit from his specialized knowledge and experience.

Radio Research Laboratories.—Interest is in radio propagation and any factors affecting it, particularly in the region from 50 to 200 miles above the earth known as the ionosphere. Present researches include observational and theoretical studies of upper atmosphere conditions and variations, mainly by radio methods. The information so obtained has always had important practical application in improving the efficiency of radio communication, and it is now becoming of increasing interest in examining its relation with meteorology and assessing its influence on projectional flight.

The research work now in progress or planned will play an important part in the co-ordinated programme of world-wide investigations during the International Geophysical Year in 1957-58.

The Board's Chairman is also Chairman of the Australian National Committee of Radio Science appointed by the Academy of Science to maintain co-ordination with the International Union of Radio Science (U.R.S.I.).

The recently occupied new premises at Camden, adjacent to the old field station there, which provide residential accommodation for the Chief Scientific Officer and some of the staff as well as improved laboratory facilities and space for aerial systems, will greatly improve the efficiency of the Camden and Sydney investigations.

2. CLOUD AND RAIN PHYSICS.

(Division of Radiophysics.)

This work is reported in Chapter XXVIII., Section 8.

3. RADIO ASTRONOMY.

(Division of Radiophysics.)

This work is reported in Chapter XXIX., Section 3.

4. MATHEMATICAL COMPUTATION.

(Division of Radiophysics.)

This work is reported in Chapter XXX., Section 3.

5. RADIO PROPAGATION.

(Division of Radiophysics.)

The Division is represented on the Consultative Committee on Radio Research which was recently formed from the principal organizations in Australia using radio communications and those engaged in radio research for the purpose of co-operative action towards the solution of problems arising in the use of radio communications. The Division is at present engaged on two such co-operative investigations.

(*a*) *Radio Noise Levels*.—One important factor in limiting the usability of a radio communication link is the interference produced by "noise". A survey of the radio noise levels throughout Australia is therefore being carried out. The observations are being made by personnel of the various user organizations at their own receiving sites, using modified communications receivers. The Research Laboratory of the Postmaster-General's Department has undertaken the modification and calibration of the necessary equipment. An officer of the Division who has had considerable experience in this field has undertaken responsibility for the scientific organization of the project, and for the evaluation of the results.

This co-operative venture is proceeding very satisfactorily and should, in the few years necessary to obtain an adequate sample of conditions, provide a useful picture of noise levels throughout the Commonwealth and the islands to the north.

(*b*) *Communication Anomalies*.—Unexplained failure of communications have been reported between civil aircraft and ground stations operated by the Department of Civil Aviation. The aircraft were using frequencies (around 3 Mc/s.) when, according to ionospheric predictions, communication conditions should have been excellent. The Division will be responsible for a co-ordinated investigation of this anomaly, which is being attempted by recording continuously on a 24-hour basis the signal level over two similar communication links (set up by the Department of Civil Aviation), and by simultaneously observing ionospheric conditions by means of a pulse transmitter operated by the Division.

6. RADIO NAVIGATION.

(Division of Radiophysics.)

Distance Measuring Equipment, a system originally developed by the Division which enables the pilot of an aircraft to determine his distance from radio "beacons" installed at known locations on the ground, is now in regular use on commercial air routes throughout Australia.

The Department of Civil Aviation has indicated, in general terms, its requirements for the addition of facilities to the existing chain of D.M.E. stations, whereby a ot could also obtain his bearing from known ground tions. The Division is investigating means by which s desirable facility might be provided. A method lding some promise involves the use of a rotating antenna stem, together with equipment in the aircraft which ables the phase of the signal received in the aircraft be compared with that of a reference signal emitted the transmitter, as a fixed point on the rotating antenna stem passes through north.

The design of an aerial mount capable of rotating at 500 r.p.m. has been completed and equipment is being sembled so that tests may be carried out.

7. Semi-conductors and Transistors.

(Division of Radiophysics.)

Intensive research into the properties and behaviour of aterials which are neither conductors nor insulators— d hence are known as semi-conductors—has followed e discovery that devices of semi-conducting material— nsistors—can be constructed whose characteristics nder them eminently suitable for some fields of use pre- ously relegated exclusively to electronic valves. The vision is investigating the basic physical properties of mi-conducting materials, and the techniques required r producing this material in a form suitable for use in nsistors. This involves the growth of single crystals, g. of germanium and silicon, of extraordinarily high rity; the introduction in minute but controlled amounts selected impurities to provide the desired properties; d the construction of sample quantities of transistors for st and measurement.

(*a*) *Fundamental Investigations.*—Experimental work s continued in three principal investigations: (i) the owth of monocrystals of germanium and silicon; (ii) the velopment of alloyed junction transistors capable of itching large currents; (iii) the distribution of charge- rriers in a semi-conductor under non-equilibrium nditions.

In the growth of single crystals of pure germanium, ecial attention has been given to material of as high degree of perfection as possible, particularly with spect to dislocations in the crystal structure. Work has so been done on the solidification of germanium (at mperatures well below the melting point of pure ger- anium) from alloys with elements such as indium. It is und that the shape of the liquid-solid interface may adily be determined, and this has been studied for growth different crystallographic orientations.

Small quantities of experimental junction transistors, th p-n-p and n-p-n types, have been fabricated by the loying technique. The aim is to develop a transistor itch capable of passing a current of 40 amperes in e "on" condition, while passing negligible current der an applied potential of 25 volts in the "off" con- tion; the unit is required for the Division's programme in nsistorized Distance Measuring Equipment. A p-n-p it with these properties has been developed; further ork is proceeding with the aim of reducing the switching me to a value of ¼ microsecond.

(*b*) *Transistor Circuit Development.*—Development of transistorized version of the airborne Distance Measur- g Equipment (D.M.E.) which is at present in service Australian airlines is continuing. This equipment mprises a small pulse-transmitter capable of 400 watts ak power output at 206 Mc/s., a 224 Mc/s. receiver, d an automatic ranging unit with meter presentation. any of the functions required in the D.M.E. involve the neration and manipulation of low-power pulses and n be carried out without great difficulty using transistors. ecial problems are arising, however, where very long memory" time-constants are required, and also where libration accuracy is affected by the temperature sensi- rity of the parameters of germanium transistors. How- er, means of overcoming these difficulties are being found; and it is also expected that they will be minimized when silicon transistors become freely available. The only position in which there is not prospect of using transistors in the foreseeable future is in the transmitting oscillator; a new principle will need to be discovered to extend the operation of transistors to the necessary frequency and power range. Encouraging progress is being made towards transistorization of the transmitter modulator where the problem is to generate pulses of 1 kW. peak power with a fast rise time. A switching transistor has been designed for the purpose but the "turn-on" time of models produced so far is still too large. The receiver will use a valve as local oscillator for the time being, but even this will be eliminated when experimental high-frequency transistors become readily available.

The application of transistors in D.C. convertors is also being studied and an automatic power regulator for the Division's induction heater is under construction.

8. Ionosphere.

(Radio Research Board.)

All long-distance radio propagation takes place through the ionosphere. The normal ionosphere is maintained in its ionized condition mainly by radiation from the sun and therefore shows daily and seasonal variations. These are now reasonably well known for most regions of the Earth. Less is known about the abnormalities, such as ionospheric storms, which disrupt radio communication from time to time, particularly when sunspots are active on the visible solar disk. The method most used for studying the ionosphere involves reflection of radio signals. With techniques now in use it is possible to record ionospheric conditions continuously and also to study disturbances travelling through the ionosphere and the moving ionization trails caused by meteors.

(*a*) *Regular Variations.*—Theoretical studies continue to increase the understanding of the regular processes in the ionosphere which are subject to diurnal, seasonal, and sunspot cycle variations. Recent deductions regarding the effects of diffusion have taken this another stage forward.

(*b*) *Winds and Movements.*—The ionosphere is subject to atmospheric winds and ionospheric drifts and to travelling disturbances which may be affected by either or both of these. Observation of movement by radio means is possible in the two main regions; the upper or *F* region 150-250 miles above the Earth and the lower *E* region at a height of some 50-100 miles.

Studies of *E* region winds are in progress at Adelaide by observing meteors and at Brisbane and Sydney by observing moving patches of ionization.

Recording the progress of travelling disturbances continues to supply factual information concerning the *F* region. This is the main line of work at present at Sydney and Camden, mostly by day, and work has also been done along similar lines at Brisbane at night. Theoretical aspects of these results are under constant review.

Radio has so far provided almost the only means of obtaining information from this region but rockets are likely to soon be reaching this height.

(*c*) *Magnetic and Ionospheric Storms.*—Some eruptions on the sun have delayed effects on the earth resulting in variations in the magnetic field known as magnetic storms and associated effects in the ionosphere known as ionosphere storms. These affect radio propagation, generally adversely, for periods up to three days after the commencement of the storm. Investigation by Board officers has shown that the radio effects can be predicted once a storm has begun, and the practical application of this information is being investigated in collaboration with the Ionospheric Prediction Service of the Department of the Interior.

XXVIII. ATMOSPHERIC PHYSICS.

1. General.

The Organization is undertaking a number of basic studies of the physics of the atmosphere with the object of attaining a more fundamental understanding of the weather and the processes which control it. Meteorology is a public utility on which almost every phase of the community life depends in some way. It already provides a wide range of services to the public, but these can prosper and improve only against a background of basic research into the many problems yet unsolved. Furthermore, Australian scientists have played a leading part in a series of experiments in rain physics, which could lead to results of great interest for a continent such as Australia which lacks adequate water supplies over wide areas.

The Organization's major investigations in the field of meteorology are undertaken by the Division of Meteorological Physics at Aspendale, Victoria. This work includes studies of dynamic meteorology, general circulation, convection, and micrometeorology, including its application to frost prevention (*see* Sections 2-7 of this Chapter). The Division of Radiophysics, on account of its access to the radar techniques employed in this work, is engaged in a careful scientific study of the processes in nature which give rise to cloud and rain, and of possible methods of stimulating rainfall by artificial means (*see* Section 8 of this Chapter).

Division of Meteorological Physics.—The Division aims at closer understanding of the behaviour of the atmosphere, both to improve the prediction of its effects and to utilize them to the greatest advantage.

Meteorology is an international science, and international aspects of the work have continued to receive attention. The World Meteorological Organization has in recent years set up working groups in special subjects, and the Chief of the Division is a member of that on microclimatology, chairman of the newly formed group on atmospheric diffusion, and a member of the executive committee of the International Meteorological Association, one of the divisions of U.G.G.I., while Mr. W. C. Swinbank has been appointed to the ozone commission of that body. The decision of U.N.E.S.C.O. to hold a conference on Climatology of the Arid Zone in Australia later this year is a recognition of the country's stake in and contribution to this field.

Work has begun on the extension to the Division's building at Aspendale, Victoria, to provide more space particularly for physical laboratories, the instrument workshop, and an adequate synoptic laboratory. The wind tunnel room was completed and the wind tunnel installed, with the addition of a smaller working section to give air speeds up to 55 m.p.h.

2. General Circulation.

(Division of Meteorological Physics.)

The studies of the general circulation previously reported have been temporarily set aside to allow a greater concentration on problems of more immediate local significance to the Australian region.

3. Dynamic Meteorology.

(Division of Meteorological Physics.)

(*a*) *Large-scale Circulation.*—The study of interactions between monsoonal and general circulations in the Australian region is being extended to the trade wind regime and the distribution of rainfall over the continent.

Special observations on "cool changes" from a large number of places in south-east Australia have now been taken for two summer seasons. These have been collated with the more routine observational data, and the statistics of the phenomenon over the whole region are being built into a semi-climatological survey. It has been found that the speed of movement varies through the day, and th results in the change tending to occur at preferred times day, which vary comparatively little from place to plac Upper wind observations at the coast show that th sloping frontal surface (shear zone) is distorted, and th bears on the complex problem of the multiple structu of these changes. Intensive field work was carried out a wide region centred on Mount Gambier in Januar 1956, in co-operation with the Bureau of Meteorology an voluntary helpers, supported by a temporary increase the network of local recording stations.

A quite strong vertical circulation has been found occur near the elevated part of the shear zone. Th may well derive much of its energy from surface heatin and affect the speed of movement of the changes.

A general method has been developed for calculatin energy changes involved in disturbing a dry atmospher and which has application to the above problem and that of frost prevention, among others.

(*b*) *Wind and Pressure Surges.*—Wind surges are feature of many regions of interest, particularly Antarctica where their suddenness and violence ha hitherto defied explanation. A new dynamical treatme of katabatic (downslope) flow accounts for the disco tinuity and associated phenomena, and should prov relevant to the genesis of discontinuities in other region A formula has been developed for the position and charac ter of the jump in terms of conditions up- and downstrea

The South Australian field data provided useful info mation on the behaviour of penetrating sea-breezes an should help to explain late-evening wind surges in place such as Renmark and Kalgoorlie.

A sensitive microbarograph has been constructed fo the observations of pressure jumps, &c, associated wit cool changes. Pulses caused by H-bomb explosions Bikini Atoll (distance 3,500 miles) have been recorde

4. Convection.

(Division of Meteorological Physics.)

The solution for the velocity and temperature fiel above a continuous source of heat in calm conditions ha now been adapted to provide a working solution unde conditions of wind. Fair agreement is obtained wit measurements on plumes from factory chimneys an smaller sources, and a basis now exists for estimate under quite general conditions in the many problem (atmospheric pollution, frost prevention, flying cond tions, rain physics, air conditioning) in which convectio plays a part.

This solution is capable of accounting for the quit sudden change in mechanism of heat transfer fro ground to air which occurs with decrease in wind spee Further measurements of heat flux made in extrem conditions of strong heating and light wind confirm formula suggested previously, and the rate of transfer ma now be predicted from measurements of wind and tem perature gradient near the ground.

5. Micrometeorology.

(Division of Meteorological Physics.)

The principal aim has been, through detailed observatio of the fine structure of temperature, water vapour co tent, and motion, to study the turbulent mechanisms whic achieve the interchange of heat, water vapour, and mome tum between atmosphere and earth.

Earlier work has been consolidated during the pas year. In particular, the transfer coefficients for wate vapour and momentum have been found to be approx mately equal and, in unstable conditions, both substantiall less than that for heat transfer. Further spectral analys indicates that, in the transition state between free an forced convection, there are air motions with horizont scale greater than in any other condition, being sever times larger than the height above ground.

The question of response time has been under further estigation. While 2-sec. galvanometers have been nd adequate for flux measurements at heights above n. in light winds, at lower heights and in stronger winds ne decrease in response time is necessary.

here is a pressing need in agricultural research for accurate, automatic method of measuring evaporation n natural surfaces, including growing crops, over ying time intervals. Such a method, based on nniques developed for turbulent transfer studies in the ision, has reached an advanced stage of development, field trials with a prototpye model have now begun.

here is some evidence that, in conditions of strong vection, the strong temperature gradient near the und changes to approximately zero gradient at an xpectedly low level, sometimes as low as 10 m. ther measurements of the temperature profile up to m. are being made from a kite balloon.

ince most of the Earth's surface is water, more fundantal knowledge is required of the sources of atmospheric rgy, water vapour, and motion from interaction with ocean; there is a reciprocal interest in atmosphere as a trolling factor in ocean currents and temperatures, and in fisheries' problems. Micrometeorological observas have been made during October, 1955, from the .V. *Derwent Hunter* operating in Port Phillip Bay and nearby waters of Bass Strait. A large number of wind files up to 45 feet have yielded useful information on the tional stress between atmosphere and ocean, which find application in the study of wind-driven ocean rent systems. Records of the turbulent fluctuations of d and temperature were also taken, preliminary to the asurement of heat exchange between the sea and osphere.

he Division has acted in an advisory capacity for blems relating to primary production and has lertaken the construction of special apparatus for a nber of other Divisions and institutions outside the nmonwealth Scientific and Industrial Research ganization. A small group has been formed to mote' this activity further. The development of rumentation for a mobile microclimate station is well anced. The Division provides for outside bodies a bration service for anemometers and air meters.

Vork has started on the installation of a battery of large (diameter 5 ft. 3 in.) lysimeters, intended primarily the study of evapotranspiration under controlled soil isture conditions. Later work envisaged embraces a le range of problems, mainly of agricultural interest.

6. FROST PREVENTION.

(Division of Meteorological Physics.)

he current series of trials on the use of wind machines frost prevention were completed during the year. The l points to be investigated were the effects of air jet ght and of crop type on the area covered.

he coverage has been found to increase with increasing ght of the air jet, but the performance of the machines ears to be largely independent of the crop type, proed the mixing action of the jet penetrates adequately ground level.

7. OZONE INVESTIGATIONS.

(Division of Meteorological Physics.)

Atmospheric ozone, though small in total amount, kes an important contribution to the radiation balance the atmosphere, and there is a close connexion between one content and latitude, season, and synoptic situation. easurements have been made for some years under ernational auspices in a number of countries, mainly in northern hemisphere. The three Dobson spectrootometers in Australia have now all been adjusted and librated in the Division, and regular measurements have been made at Aspendale during the past year.' It is proposed to continue these, and the other instruments will be installed soon at Macquarie Island (52° S., 159′ E.) and Brisbane (27° S., 153′ E.) in collaboration with the Australian National Antarctic Research Expedition and the Bureau of Meteorology respectively, in preparation for observations during the International Geophysical Year.

8. CLOUD AND RAIN PHYSICS.

(Division of Radiophysics.)

The experimental investigations of the physical processes responsible for the formation of cloud and rain which were initiated in the Division in 1947—following the successful demonstration that some clouds could be induced to rain by artificial means—have been actively continued. The original objectives were to provide a sound background against which this potentially important discovery might be assessed, and an indication of whether or not it might be possible to produce economically significant increases in rainfall by artificial means.

While related work has also been proceeding in other countries of the world, it is largely as a result of investigations carried out in Australia that the basic problems involved are now more clearly understood. There are two quite separate processes by which rain occurs in Nature: by ice-crystal formation in supercooled clouds, and by the coagulation or coalescence of water droplets in clouds which are warmer than freezing. The Division's work, described in earlier Reports, has established the vital role played in both types of rain by certain minute dust-like particles in the atmosphere known as " nuclei " and has demonstrated that by supplying appropriate substitutes when naturally occurring nuclei are absent or ineffective, rain may be induced artificially. There are indications that supercooled clouds are the more important from the point of view of artificial rainmaking. Work has therefore been devoted during the past year, for the most part, to a detailed study of the nature and occurrence of natural " freezing " nuclei (which are responsible for initiating rain from supercooled clouds) and to field experiments designed to show whether useful increases in rainfall may be induced by the use of the most effective source of artificial freezing nuclei yet discovered, viz., silver iodide.

(*a*) *Cloud Formation and Cloud Properties.*—(i) *Warm Clouds.*—" Project Shower ".—The Division has been responsible for editing and preparing for publication the observations made by the numerous individual participants in this interesting co-operative study of the processes involved in the formation of warm rain which was carried out in Hawaii. This task has now been substantially completed.

(ii) *Cloud Droplet Spectra.*—Measurements of the size and concentration of droplets in maritime and continental cumuli show a systematic difference, the droplet concentration being higher by a large factor in continental cumuli. While the speed of updraught is one important factor in determining the droplet spectrum in a cloud, it is insufficient to explain the marked contrast between cumuli formed over land and over sea. The presence of giant sea salt nuclei in maritime clouds also appears unable to account for the differences found, which may arise from the presence of droplets of intermediate size, at present beyond the range of existing measurement techniques.

(iii) *Electric Charges on Cloud Droplets.*—Experiments in the laboratory have shown that the rate of coalescence between droplets can be markedly increased by introducing charges of opposite sign, and reduced by charging all droplets to the same sign. Coalescence, and hence the liability to produce rain, in a natural cloud is likely to be modified if the droplets become charged.

Preliminary experiments were initiated last year to determine whether the droplets present in natural clouds do, in fact, carry electric charges. A method has been developed in which the paths taken by cloud droplets are photographed as they fall through a region in which an electric field is set up. The electric field is reversed at periodic intervals, which results in any charged particles executing a zig-zag path, from which the sign and magnitude of the charges on each drop can be determined. The results obtained with improved and more sensitive equipment operated on a mountain summit showed that a high proportion of the droplets sampled in liquid water clouds consistently carried positive charges; and that it was only in clouds containing ice crystals that negative or mixed charges were found. It seems likely, therefore, that electric charges may play an important part in the physics of rain formation.

(*b*) *Rain.*—During the past year convincing evidence has been found that naturally occurring freezing nuclei—the minute aerosols which provide the essential triggering action that causes supercooled clouds to rain—are much more abundant and active on some days than on others, and that this occurs on the same days at widely separated localities, apparently on a world-wide basis. That this discovery is likely to be of far-reaching importance to practical meteorology is indicated by the fact that these days of high nucleus count appear to be fixed in relation to the calendar and occur on or close to the calendar dates on which, taken over a long period of years, more rainfall has already been shown to have occurred.

(i) *Measurement of Freezing Nucleus Concentration.*—Freezing nucleus measurements have been made in previous years by estimating visually the numbers of ice crystals formed when samples of the outside air are admitted to a "cold box" fitted inside an aircraft. The ice crystals are detected by the scintillations produced in a strong beam of light, but the observations are subjective and it is difficult to distinguish ice crystals from other particles with certainty. An improved technique has been developed during the year which does not have these disadvantages, and is likely to become generally adopted for freezing nucleus measurements. In this method ice crystals formed in a cold chamber are allowed to fall into a shallow layer of a solution of sugar in water, which has been supercooled by a few degrees. They then grow rapidly (but at a rate which can be controlled) and after about one minute are large enough to be counted easily and accurately. The equipment itself is relatively simple and portable; numerous tests with it show that measurements may usefully be made at ground level at sites free from contamination by low-level dust, smoke, and other pollution.

(ii) *Variations in Freezing Nucleus Concentration.*—Last year it was reported that the nucleus count during the month of January was substantially higher on some days than on others, and that the maxima apparently occurred simultaneously at widely separated localities, This has been confirmed by further measurements organized by the Division and made in Australia, South Africa, and California, United States of America, during January, 1956.

A particularly complete and striking series of measurements covering the period November, 1955, to February, 1956, was carried out at Carnarvon, Western Australia, this site being chosen because of its freedom from cloud and rain at that time of the year, and because the prevailing on-shore wind ensured that the air would be free from pollution by dust and smoke. These showed features similar to those previously observed for the month of January, namely, periods of minor variations separated by brief periods when the nucleus count attained abnormally high values. The dates of the latter were not related to local wind and weather over the region, but were in close agreement with those on which, over a period of years, substantially more and heavier rainfall has been recorded.

It was also found that the number of occasions on whic high cloud of cirriform type was reported over Wester Australia was markedly greater around the dates on whic the nucleus count was observed to be high.

(iii) *Meteoritic Dust and Rainfall.*—Examination o rainfall data covering long periods from additional place throughout the globe lends further support to the revolu tionary theory, reported last year, that rainfall tends to b greater on certain "preferred" dates of the calendar yea and from the fact that these dates occur approximatel 30 days after the Earth's passage through the orbits o the various meteor streams known to belong to the sola system, the cause is probably the minute particles o meteoritic dust which enter the Earth's outer atmospher at those times, and slowly settles to the lower cloud-bearin levels. The measurements of freezing nuclei reporte above are obviously consistent with this theory.

Attempts are being made, by more direct physic methods, to check whether meteoritic dust is, in fac responsible. One series of experiments is designed t detect the presence of dust layers and to trace the passage through the atmosphere by observing whethe there are discontinuities in the amount of sunlight scattere at various heights. Preliminary results indicate tha increased scattering can be detected at great heights, an that there appears to be a tendency for this to be mor marked near days of known meteor showers. More sens tive equipment has been designed and the observations a being repeated. Samples of the nuclei are also bein collected from aircraft at high altitudes for caref chemical and physical analysis.

In order to provide current information on the inciden of meteor showers, particularly those which are observab only in the southern hemisphere, regular observations b radio methods are being carried out with equipme developed by and installed at the University of Adelaid by an officer of the Division stationed at Adelaide.

(*c*) *Artificial Rain Formation.*—Experiments describe in previous Reports have suggested that seeding of supe cooled clouds with artificial freezing nuclei offer the mo economically attractive method of inducing worth-whil increases in rainfall. Silver iodide is the most effecti source of such nuclei yet discovered. During the past yea cloud seeding with silver iodide has been carried out on routine basis in two selected areas. Further tests ha also been made on the behaviour of silver iodide nucl in the atmosphere.

(i) *The Properties of Silver Iodide.*—The metho almost universally used in commercial rainmaking oper tions in other countries has been to burn a solution silver iodide in a "smoke generator" on the ground (called because it produces a "smoke" consisting of minu crystals of silver iodide), and to assume that air curren and general turbulence will carry the material to hig levels in the atmosphere. Previous work by the Divisi has shown that this assumption is unjustified, and th silver iodide particles released at ground level do not, general, diffuse to high altitudes—and, equally importan they may lose their ability to form ice crystals soon aft leaving the generator.

Both these aspects of the behaviour of silver iodide ha been carefully checked by further tests during the pa year, during which it was shown that whereas the deca in effectiveness is rapid during daylight, it is negligib during hours of darkness. The implications are, clearl that if seeding with silver iodide is to have a reasonab chance of success the particles must be generated und conditions which ensure that they reach the supercool regions of the atmosphere as soon as possible after releas The most effective way of doing this is to release the smok at the appropriate level in the atmosphere, and speci generators that can be fitted to aircraft have been designe Techniques for checking the actual output of these gene rators when in operation, by detecting the silver iodid smoke in another aircraft and measuring its activity an distribution, are being developed.

(ii) *Cloud-seeding Operations with Silver Iodide.*—Two cloud-seeding operations have been set up in separate areas of south-eastern Australia.

(1) The Kiewa Project is designed to test whether useful results may be obtained with a silver iodide ground generator when sited under the most favourable conditions, i.e. in a high mountain area where the necessary updraughts to carry the seeding material rapidly to high altitudes might be expected to occur. In co-operation with the Victorian State Electricity Commission a ground generator is being operated on Mt. Stanley (3,400 feet) in north-eastern Victoria, the objective being to determine whether increased precipitation is induced over the Kiewa Catchment area. The generator has been operated on suitable occasions, i.e. when cloud has developed and the wind is from the appropriate quarter (approximately north-west), since 1954. No significant effect on the rainfall over the target area was disclosed after fifteen months' operations. The output of the generator has therefore been substantially increased, and the experiments will be continued at the new output rate for a further year or more.

(2) The Snowy Mountains Project is being conducted in co-operation with the Snowy Mountains Hydro-electric Authority, over a portion of the area controlled by the Authority. It was initiated in June, 1955, and will continue for a period of several years. Seeding is being carried out over a defined "target" area by means of silver iodide smoke generators mounted in the Division's experimental Avro Anson aircraft, and the rainfall over this area is compared with that which falls on an adjacent unseeded "control" area.

The weather in this region may be divided into well-defined natural periods determined by the passage of successive pressure systems. Seeding, however, does not take place during every such period, but only during those which have previously been selected on an entirely random basis. The experiment has been designed in this way in order to provide the best possible chance of detecting any effects due to the seeding, the essential comparison between the natural rainfall over the target and control areas being obtained from the data derived during periods when no seeding takes place.

The operations will need to continue for a long period before results of reliable significance can be expected, but there are indications that the rainfall over the target area has been greater during the seeded periods.

(*c*) *Electrical Techniques.*—Preparations are being made to check whether it may be practicable to increase the coalescence rate within a cloud to the point where rain is induced, by artificially charging cloud droplets to opposite polarities. This has been suggested as feasible as a result of other work by the Division which has established that the coalescence rate between droplets is markedly increased in a population of mixed charges, and that natural clouds tend to contain only droplets which are positively charged.

Equipment to develop the very high voltages required has been designed and tested, in readiness for fitting within the bomb compartment of a Lincoln aircraft, made available through the co-operation of the Royal Australian Air Force.

XXIX. EXTRATERRESTRIAL PHYSICS.

1. GENERAL.

The new science of radio astronomy—the study of the universe by means of radio waves—is now recognized as an important and integral part of astronomy itself. Apart from providing information which supplements that obtained by optical methods, it has led to entirely new discoveries which could not have been made by the methods of classical astronomy. A more recent development, which is certain to shed light on the origin and structure of galaxies—including that to which the Earth belongs—is the discovery of a radio "spectral line" at a wavelength of 21 cm., due to atomic hydrogen.

Radio astronomy has formed a major part of the research programme of the Division of Radiophysics (*see* Section 3 of this Chapter). Studies of the ionosphere are carried out by the Radio Research Board (*see* Chapter XXVII., Section 8). Work on solar radiation is carried out by the Division of Physics (*see* Section 2 of this Chapter) and cosmic ray investigations at the University of Tasmania (*see* Section 4).

2. SOLAR PHYSICS.

(Division of Physics.)

(*a*) *Theoretical Studies.*—Theoretical methods have been developed for predicting the strengths of various spectral lines emitted or absorbed by hot atmospheres in the absence of thermodynamic equilibrium, and application has been made to the interpretation of the spectra of prominences and flares. A consistent picture has emerged from an analysis both of the hydrogen H_α and helium D_3 prominence lines, showing that the prominence temperature is normally in the range 10^4 to 2 x 10^{4}° K., with electron concentrations in the range of 10^{10} to 5 x 10^{10} cm.$^{-3}$; and that the ratio of the abundances of helium and hydrogen atoms is in the range 0.12 to 0.4. For the spectral lines H_α and D_3 the major part of prominence emission turns out to be due to scattering by the prominence of radiation incident on it from the solar disk.

An analysis of present data shows that in flares also the temperatures lie normally in the range 10^4 to 1.5 x 10^{4}° K., but the electron concentrations are higher than in prominences, and are in the range 5 x 10^{11} to 10^{13} cm^{-3}.

(*b*) *Chromospheric and Prominence Observations.*—Since the beginning of 1956, H_α filtergrams have been obtained on 35-mm. film at half-minute intervals on a routine basis. Co-operation has been maintained with the Fraunhofer Institut, Freiburg, in the supply of daily H_α filtergrams for incorporation in their daily charts of solar activity.

Preliminary studies of chromospheric granulation have shown that there is no significant correlation between elements spaced further than 3 x 10^4 km. apart, and that the life-time of individual granules is of the order of 5 hr.

(*c*) *Solar Physics Field Station.*—During the year a field station has been in the course of erection at Fleurs, some 30 miles west of Sydney, to facilitate high-resolution cinematography of the solar chromosphere and photosphere.

3. RADIO ASTRONOMY.

(Division of Radiophysics.)

The Division of Radiophysics now has in operation a unique collection of powerful instruments for the study of radio astronomy; the solar radio spectrometer, the 85 Mc/s. Mills Cross (1,500 feet in extent), and a new 19 Mc/s. Mills Cross of 3,500 feet. The original multi-element interferometers used for the study of the Sun have been dismantled and are being replaced by a multi-element cross which utilizes the principles of the Mills Cross. It will scan the Sun, television-wise, and will provide a day-by-day picture comparable in detail with that given by the human eye. All these instruments were devised in the Laboratory; all are being copied in the United States. In a few years' time, when the existing instruments will have mostly completed their useful functions, the giant radio telescope will become available.

As mentioned in Chapter I. and Chapter XXVII., further generous donations including 250,000 dollars from the Rockefeller Foundation, have made it virtually certain that adequate funds will become available for the projected giant radio telescope. In consequence, work on the design has been initiated with the placing of a design study contract with the well known London firm of consulting engineers, Freeman, Fox & Partners.

(*a*) *Radio Waves from beyond the Solar System.*—Two types of radio waves are received from beyond the solar system; one which is observable over a wide range of wavelengths but which is stronger at longer wavelengths; and the other, a radio " spectral line " at a wavelength of 21 cm., arising from interstellar hydrogen. Outstanding observations of the former are in progress using the two Mills Crosses, and are giving a wealth of detail concerning the discrete sources and the background radiation.

The 1,500-ft. cross, which has a beam width of 50 minute arc at its wavelength of 3½ m., has now been in operation for two years, and a systematic survey of the sky visible to it is well advanced. The observations of the general survey are partly reduced, and a large number of particular problems have been investigated. This is the first time such a detailed survey including both the discrete sources and the background has been possible. However, a survey of the discrete sources on a similar wavelength was recently completed at Cambridge. The results of this survey disagree grossly with the Division's interim results and every effort is being made to trace the cause of the discrepancy. So far no evidence casting doubt on the Sydney results has been found. Unless these results are indeed wrong, spectacular cosmological conclusions drawn by the Cambridge workers from their observations are meaningless.

In the course of the observations a large number of particular objects have been examined. For example, a considerable fraction of the nearer external galaxies were identified, sufficient to provide some statistical indication of the emission characteristic of the various types. Similarly, a number of emission nebulae (regions of glowing hydrogen) were examined and found either in emission or absorption, depending on whether the background was brighter or duller than the nebula.

As a part of the survey, the region in Sagittarius, the direction of the galactic centre, has been investigated, and brightness contours have been plotted. Previous observers had obtained discordant results. The survey showed that observers at different wavelengths had been observing different things; those at shorter wavelengths a region of ionized hydrogen, those at longer wavelengths an extended region of non-thermal emission.

The limit of resolution of this cross is 50 minutes of arc, while many of the discrete sources are a minute of arc or less in extent. A parallel set of observations was therefore undertaken at about the same wavelength using a radio-link interferometer with a base-length of several kilometres. About 70 discrete sources could be observed. This type of measurement should be extended to fainter sources, and it is planned to do this using larger aerials.

A second extension of these observations is to repeat them at very different wavelengths. This is analogous to photographing the sky in red and in blue light. A second cross working on 19 Mc/s. is just completed and preliminary observations have begun. This instrument is 3,500 feet long and has a beam width of about 1½°.

Turning now to the line radiation from interstellar hydrogen, work is proceeding on a study of the distribution of hydrogen in the southern Milky Way. The extensive observations necessary are nearing completion and are giving, when taken in conjunction with the complementary work carried out at Leiden for the northern hemisphere, a comprehensive picture of the spiral structure of our galaxy. Because of the great number of observations required for such a study the work is necessarily proceeding slowly. A new receiver which observes the complete line profile simultaneously is nearing completion, and should permit similar observations in the future to be completed much more quickly.

(*b*) *Solar Radio Waves.*—The Division of Radiophysics has pioneered two main lines of development in solar radio astronomy; the study of the spectra of metre-wavelength solar bursts, and studies of very high resolution of the distribution of radio brightness over the solar disk at decimetre wavelengths. In both fields equipment is being further developed to increase the effectiveness of the observations. Both sets of observations are very relevant to the recording of solar activity which is necessary for the proper understanding of the geophysical observations to be made all over the world during the International Geophysical Year. Neither has previously been attempted elsewhere, although similar but not identical equipment will be set up in America in the near future in order to try to extend the hours during which the Sun can be observed each day.

The radio spectrometer is being extended by the provision of facilities for observing both polarization and the place of origin on the Sun. The first is desirable because the emission may be associated with solar magnetic fields, and polarization is an indicator of this; the second because the spectrum observations have suggested that certain disturbances arise in explosively ejected streams of gas, and it should be possible to verify this by directional means. Initial observations of both polarization and position have been made, but the system requires alterations so as to be capable of an extended series of observations.

The instrument for observing the detailed brightness distribution over the Sun at a wavelength of 21 cm. combines the principles of the Christiansen multi-element interferometer and the Mills Cross. It will consist of two rows, each of 32 paraboloids of 19-ft. diameter, arranged in the form of a cross. Each row is 1,240 feet long. The system gives a number of pencil beams in the sky, each 2 minutes of arc in diameter. Successive beams will scan the Sun, television-wise, and will build up a picture of what it looks like while using radio waves, i.e., a radioheliogram of the Sun. Preliminary work on the Sydney model is complete, and the erection of the aerials is now proceeding.

Routine observations at single frequencies are being continued, and similar observations from all over the world are edited in this Division prior to publication in the International Astronomical Union's Bulletin on Solar Activity.

(*c*) *Radio Waves from Jupiter.*—Early in 1955, workers in America discovered that Jupiter emits radio waves, but the nature of the emission was a mystery. Equipment to search for the waves over a number of hours each day was set up near Sydney, and a number of old records of cosmic noise taken at times when Jupiter was in the beam of the aerial were examined. It was discovered that the strong emission occurred infrequently and spasmodically, but the times when it was observed were correlated with Jupiter's rotation. In fact, over a period of months, emission was observed only when a particular section of Jupiter was facing the Earth. It follows that the emission at that time was restricted to a small area on the planet, quite unlike, for example, the distributions of thunderstorms over the Earth. Other facts were gathered—the frequency of occurrence, variation with wavelength, degree of polarization, and so on—but they are, so far, insufficient to provide an explanation of the mechanism of emission, which is a greater mystery than when it was discovered.

(*d*) *Electromagnetic Theory.*—The mechanism of origin of solar and cosmic radio waves is not yet properly understood, but contributions which are probably important arise from high-energy electrons moving in magnetic fields. Consequently, the study of phenomena in highly rarefied gases in the presence of magnetic fields is related to radio astronomy. It is also significant in many other branches of astronomy. Such studies are in progress and have led to important generalizations concerning the types of waves which can occur in such media. They have also given evidence for a cause of heat dissipation which may be important in the heating of the solar corona.

4. Cosmic Ray Research.

(University of Tasmania.)

During the present financial year funds provided by the Organization are being used mainly to provide the salaries of part-time assistants carrying out the analysis of data obtained from equipment in operation at Hobart and the re-examination of past results from Antarctic bases of the Australian National Antarctic Research Expedition. Work on the following topics is being assisted in this way by the Organization.

The diurnal variation of the east-west difference and the long-term drift in the value of the east-west asymmetry of cosmic rays have been investigated. A paper on the first of these projects was presented in September, 1955, at an international conference on cosmic rays at Guanajuato, Mexico.

A diurnal variation of the pressure coefficient for the penetrating component of cosmic rays has been observed. A paper on the implications of this in the correction of data for atmospheric effects should be ready for publication in the near future.

Preliminary work has commenced on the calculation of the trajectories of particles arriving at the earth from various directions after deflection in the earth's magnetic field. This is important in its application to the interpretation of solar flare effects, such as occurred on 23rd February, 1956. A paper on the observations at Hobart, Macquarie Island, and Mawson during this event has been accepted for publication.

XXX. MATHEMATICAL STATISTICS AND MATHEMATICS.

1. General.

Mathematical work plays an important part in all phases of the Organization's research programmes. A separate Division of Mathematical Statistics is maintained to provide workers in the various Divisions and Sections with specialized help in planning their researches and analysing their experimental results (*see* Section 2 of this Chapter).

Work on mathematical instruments and mechanical and electrical methods of computation is undertaken in the Section of Mathematical Instruments (*see* Section 4 of this Chapter). Work on computing equipment is also undertaken in the Division of Radiophysics (*see* Section 3 of this Chapter).

2. Division of Mathematical Statistics.

In the period under review, only one major change has been made in Divisional organization. Responsibility for the former collaborative investigations with the Division of Animal Health and Production, on breeding and genetical studies in sheep, has been undertaken entirely by the latter Division, and the staff concerned have accordingly been transferred.

Advisory assistance has been provided to an increasing extent to the personnel at each Divisional centre, and to Government departments, private research workers, and others. Investigations associated with various aspects of the Organization's programme are discussed elsewhere in this Report. Recent developments in the Division's own research interests include multivariate analysis; applications of the theory of group representations in experimental design; the analysis of farm survey data; statistical quality control; significance tests for discriminant functions; and further work on the intercorrelations of rainfall at given observing stations, with the object of increasing the accuracy of prediction at intervening points.

Great stimulus resulted from the visit, at C.S.I.R.O.'s invitation, of Professor M. G. Kendall, Professor of Statistics, and Director, Division of Research Techniques at the London School of Economics. Professor Kendall spent the major part of his time in C.S.I.R.O. laboratories, discussing problems with Divisional staff, and addressing small gatherings on specialized topics. His visit culminated in a conference on mathematical statistics (the first of its kind to be held in Australia), in Melbourne, which was attended by interstate representatives from statistical and mathematical departments of universities and other interested bodies, along with the staff of this Division and other officers of the Organization.

Interest and stimulation were maintained when, immediately following Professor Kendall's visit, Professor S. S. Wilks, Professor of Mathematical Statistics at Princeton University, United States of America, came to Australia, under the sponsorship of the Carnegie Foundation, for the specific purpose of studying the teaching of statistics in the universities, and research in Mathematical Statistics in C.S.I.R.O.

3. Mathematical Computation.

(Division of Radiophysics.)

Following the decision made last year to transfer on loan to the University of Melbourne, the electronic computer developed by the Division of Radiophysics, the machine has been erected by the Division at its new site, and was formally handed over to the University of Melbourne at an official opening on 14th June, 1956. It will be operated jointly by the Departments of Mathematics and Physics.

4. Mathematical Instruments Section.

The Section has continued to work in close co-operation with the Electrical Engineering Department of the University of Sydney in both aspects of its research programme, which involve the operation of the differential analyser and the development of new equipment.

The major problems solved by using the differential analyser were: (*a*) a continuation of the power system stability problem by the University of Sydney; (*b*) further studies of the undamped free pulsations of an ideal bubble, carried out jointly by the University of Sydney and the New South Wales University of Technology; (*c*) investigation of non-linear control systems by the Radiophysics Division; (*d*) an examination of factors affecting the design and operation of a saltfield.

The second aspect of the programme is the development of a digital differential analyser in co-operation with the University of Sydney. Machines of this type have recently been developed overseas and appear to be particularly well suited to the solution of non-linear hydraulic problems of the type required by the Snowy Mountains Hydro-electric Authority. The new machine will use junction transistors instead of valves as its active circuit elements. Consequently it will be of relatively small size and power consumption, and can be mounted on a desk of normal size.

XXXI. RESEARCH SERVICES.

1. Libraries.

The Organization's library network has this year concentrated upon greater co-ordination of its services.

In August, 1955, advantage was taken of the eighth Conference of the Library Association of Australia in Brisbane to hold a meeting of senior librarians. Twenty were present and a stimulating interchange of ideas took place. It is hoped that regular meetings of this kind will be held in future.

As one result of the Brisbane meeting, Divisional and Sectional librarians submitted to Head Office library details of interdivisional routing. By correlating this, it has been possible to reduce the time that journals are away from their holding libraries and to reduce the costs inherent in routing generally.

Another result has been the establishment of a duplicate exchange service between C.S.I.R.O. and other libraries both within Australia and overseas. Much valuable material has been acquired in this way and a considerable sum of money has been saved.

In addition to the set of cards forming the Commonwealth Index of Translations filed under author by the Translation Section, Head Office library houses a duplicate set filed under journal. There are some 17,000 cards at present and anyone seeking a translation may refer to them.

Publication of the General Supplement to the Union Catalogue of Scientific and Technical Periodicals in the Libraries of Australia has commenced. It will be typed, not varityped as before, and reproduced by photolithography. It should be available in 1957.

The increased use of the libraries of the Organization is best reflected in the rise in the number of requests for specific references, subject bibliographies, and general subject enquiries channelled through Head Office library. During the first six months of 1954 a total of 4,565 enquiries were handled as against 10,236 for the first six months of 1956. Requests for photocopies have risen correspondingly until they now average over 200 per month.

2. TRANSLATION.

The Translation Section has performed both written and oral translation for the Divisions and Sections of the Organization. The requirements of the Organization permitted only a trivial amount of assistance to other governmental bodies and scientific workers. Outside translators were used for some of the work.

The Section has operated as Australian agent for the Index of Translations of the British Commonwealth Scientific Office. A reference card index of available translations has been kept, and has occasionally prevented duplication. Microfilm copies of all translations made by the Section from Russian have been prepared for the National Science Foundation, United States of America.

The languages that can be handled by the Section are: German, Dutch, Swedish, Norwegian, Danish, Icelandic, Latin, French, Italian, Spanish, Portuguese, Russian, Polish, Ukranian, Lettish, and Hungarian. For other languages use must be made of outside translators.

3. ENGINEERING SECTION.

Whilst a number of Divisions and Sections undertake work of an engineering nature, the Engineering Section is engaged principally in the field of applied thermodynamics, the utilization of solar energy, and a study of electronic control systems required for this work. The Section has developed from the former Central Experimental Workshops which was established some years ago to undertake the design, development, and manufacture of special equipment and installations for other Sections of the Organization. This work has been continued and extended; in fact, many of the engineering investigations in which the Section is involved have emerged from the research equipment requirements of our various Divisions. This applies particularly to the study of both growing plants and living animals in a controlled environment. Assistance in the shape of advice on special installations, as well as the design and manufacture of special-purpose machines and equipment, continues to be sought by Divisions and Sections, particularly those without engineering facilities of their own.

During the year the Officer-in-charge of the Section attended the World Symposium on Applied Solar Energy at Phoenix, United States of America, and presented a paper on solar water heaters.

(*a*) *Air-conditioning and Refrigeration.*—Precise control of temperature and humidity is being found necessary to an increasing extent by workers in many different scientific fields. To meet these broad requirements a standard laboratory air conditioner has been developed with considerable flexibility to cope with the range of requirements. The conditioner applies proportional control to its heating and cooling operations, and also to humidification and dehumidification. Using commercial sensing elements it can, under normal conditions, control temperature to within ± 1° F., and relative humidity to within 1.5 per cent. The unit has been designed for easy installation in existing laboratories and does not occupy floor space within the laboratory.

In order to maintain close temperature control using dry expansion cooling coils, a by-pass injection refrigeration system has been developed which enables the evaporator to be maintained at substantially constant temperature irrespective of load. Accordingly it has been found possible to maintain temperature within very close limits without having recourse to brine systems with their attendant thermodynamic inefficiency and added complications.

A small, automatic three-phase electrode humifier has been developed to supply steam for humidification, and work is at present being carried out on a similar single-phase unit.

Some work is in progress on the accurate control of temperature and humidity in large spaces using a multiplicity of relatively small units. This has application in the textile industry and the work is being carried out in conjunction with the Wool Textile Research Laboratories.

For more precise temperature and humidity control than can be obtained by using commercially available sensing devices, electronic control systems have been developed. For temperature control, thermistors are employed, whilst the sensing device for humidity is a modified form of the electrolytic hygrometer developed by the Division of Physics. Stability of operation is always a factor to be considered in any control system, and a novel type of thermal delay is being used for this purpose.

The suitability of the heat pump under Australian conditions is being examined, particularly as a means of both heating and cooling relatively small buildings. Work is proceeding to determine the amount of heat that can be extracted from soil under specified conditions.

(*b*) *Controlled Climate Rooms.*—Construction of the two extended-range controlled climate rooms at the Sheep Biology Laboratory, Prospect, has now been completed and virtually all associated equipment installed. An extensive series of tests is at present being carried out, to check the performance of the equipment and to enable suitable operating techniques to be developed. The results obtained so far indicate that the aim will be achieved of obtaining precisely controlled temperature and humidity conditions in the rooms, corresponding to those encountered anywhere in Australia.

(*c*) *Cooling of Glass-houses.*—While much work has been done overseas on the subject of heating glass-houses, there has been no commensurate attention paid to their summer cooling which, in Australia, is generally a greater problem. The Section has developed a simple form evaporative cooler, primarily for use with the Waldor ass-house, and installations of these at Canberra and Ierbein have shown that substantial cooling can be btained by this means. This method of cooling involves e circulation of very large quantities of air at temeratures slightly higher than wet bulb temperature. It therefore suitable only in districts where high wet bulb mperatures are not encountered. Work is proceeding to mplify the equipment and improve the efficiency of vaporation.

(*d*) *Utilization of Solar Energy.*—During the past velve months experimental flat-plate solar water heaters ave been installed in the Organization's laboratories at risbane, Prospect, Canberra, Deniliquin, Geelong, and delaide. In addition, a similar heater has been put into peration at the Chiswick Field Station, Armidale, to upply hot water to the new living quarters there. Data n daily radiation absorption are being obtained regularly om all these points to supplement the figures previously btained in Melbourne and Merbein. Further developent work on the water heater is being carried out in Ielbourne, where additional equipment has now been nstalled to record and integrate incident radiation. Conderation is being given to the extension of the work to ther thermal processes. Improvements in design of at-plate absorbers are being investigated with the object f encouraging manufacturers to enter this field.

(*e*) *General Engineering.*—During the year several teresting machines and pieces of equipment were eveloped and put into operation. Among these have een two pilot-scale yarn-winding machines for use in xtile research, and a twin-beam weighing apparatus with exure pivot suspensory elements and an accuracy of etter than 1 part in 10,000, for use in conjunction with a losed-circuit meat dehydrator. A nursery seed thresher, f the type previously developed for the Division of lant Industry, was supplied to the United Nations Food nd Agriculture Organization in Italy, for use with annual pecies of *Medicago* and other hard-podded legumes. Vork is at present proceeding on the construction of large experimental cheese cheddaring machine for the airy Research Section.

XXXII. PUBLICATIONS, EXTENSION, AND LIAISON ACTIVITIES.

1. General.

The Organization's research results are made available hrough various channels.

Formal scientific publication is supplemented in several vays; by the preparation of films (Section 6 of this Chapter) which may, for example, give a farmer or xtension officer more help in diagnosis of animal diseases han would a list of clinical data; by the continuous and lose contact with industry of officers of the Divisions nd Sections, through whom much information—derived rom the literature, accumulated knowledge and experience, nd current research—is disseminated; by the provision of facilities for guest workers in laboratories; by the ublication of trade circulars, newsletters, and articles or trade journals; by press releases; by lectures and hort courses of specialized training; and by the organization of specialist conferences.

The application of research in the primary industries s being assisted by the work of the Agricultural Research Liaison Section (Section 3 of this Chapter).

The application of research in the secondary industries s being assisted by the newly formed Industrial Research Liaison Section (Section 4 of this Chapter).

Section 5 of this chapter deals with the work of the Organization's Scientific Liaison Offices in London and Washington.

2. Publications.

The Organization now publishes the following eight scientific periodicals:—

Australian Journal of Agricultural Research. Six issues a year.

Australian Journal of Applied Science. Issued quarterly.

Australian Journal of Biological Sciences. Issued quarterly.

Australian Journal of Botany. Issued as material becomes available.

Australian Journal of Chemistry. Issued quarterly.

Australian Journal of Marine and Freshwater Research. Issued as material becomes available.

Australian Journal of Physics. Issued quarterly.

Australian Journal of Zoology. Issued as material becomes available.

General editorial policy is decided by an Editorial Board comprising Dr. N. S. Noble (Chairman), Professor J. S. Anderson, Professor Sir Macfarlane Burnet, Professor L. H. Martin, and Professor J. G. Wood. Editorial Advisory Committees are responsible for editorial matters affecting each individual journal, and members of the Board serve on appropriate journal committees.

The Royal Australian Chemical Institute collaborates in the publication of the *Australian Journal of Chemistry*, the Institute of Physics (Australian Branch) collaborates in the publication of the *Australian Journal of Physics*, and the Australian Veterinary Association and the Australian Institute of Agricultural Science collaborate in the publication of the *Australian Journal of Agricultural Research.*

The Organization's research results are published in the abovementioned journals, in its Bulletins and the Technical Papers of its Divisions and Sections, and in special series such as the " Land Research " series and the " Soil Publication " series. Many research papers are also contributed by officers of the Organization to specialized scientific journals both in Australia and overseas.

The journals listed above are open to receive contributions of merit from research workers, irrespective of country or of the organization to which they are attached. Many papers from workers in Australian universities and a limited number from overseas have been published and the marked increase in the annual volume of the journals represents growing support from all sources.

A complete list of scientific papers published during the year by Officers of the Organization will be found in Chapter XXXV.

3. Agricultural Research Liaison Section.

The chief aim of the Agricultural Research Liaison Section is to ensure that the Organization's research results are made available to State Departments of Agriculture for use in their extension work with farmers. The work of the Section is concerned chiefly with marshalling important research material and presenting it in suitable form to State agricultural authorities by means of publications and conferences.

A major development has followed discussions with State authorities regarding the possibility of closer collaboration regarding important agricultural regions. A pilot area comprising a complete river valley of about 600 square miles has been selected for intensive study of the physical, agronomic, and economic features associated with its agricultural development. In the first place, research results applicable to the area are being considered with relevant C.S.I.R.O. Divisions and Sections.

(*a*) *Publications.*—The quarterly periodical *Rural Research in C.S.I.R.O.* is meeting a demand for a concise description of aspects of the Organization's research which can have important practical applications.

Important subjects are selected as major themes for each issue. The September issue, for example, dealt with animal reproduction, particularly the implications of recent research on the time of mating Merino sheep. Beef industry problems, which were the theme of the December and March issues, included pleuropneumonia, cattle tick, and the work of the National Cattle Breeding Station at "Belmont", Queensland. The June issue was mainly concerned with wool textile research.

Subjects requiring more detailed treatment are appearing in the Organization's "Leaflet" series, and important research results are described in press releases.

(*b*) *Conferences.*—The Section is paying particular attention to the principles and techniques for conducting and recording conferences, and has tried out various methods involving the use of tape recorders. This has shown that with proper preliminary organization it is possible to issue summaries of proceedings for correction at the conference itself and to obtain greater accuracy and speed in preparing the final report.

Assistance given in the organization of several conferences included the preparation of a handbook describing the sheep and wool research of the Organization.

The Section is also organizing the Australian post-conference tours for delegates to the 1956 International Grasslands Conference.

(*c*) *Films and Displays.*—The Section works with the Film Unit in the production of films on rural topics and asists it with the art work associated with the Unit's general activities. In addition to work associated with publications, conferences, and films, the Section's art department is being increasingly used to help with displays.

(*d*) *Talks.*—Officers of the Section gave talks on the Organization's agricultural work to various groups, including overseas students and staff training schools.

(*e*) *Inquiries.*—About 1,000 inquiries were received during the year from extension workers, research officers, schools, pastoral companies, banks, individual farmers, and others interested in the agricultural development of Australia. Many were answered direct and others were referred to appropriate research or extension authorities. In several instances, the required information was supplied in the form of a report based on material obtained from several different authorities and collated by the Section.

4. INDUSTRIAL RESEARCH LIAISON SECTION.

This small section has a responsibility for providing a liaison service in fields that are of common interest to the Organization and to industry. The Section has collaborated with the Australian Institute of Management in arranging discussion groups on various aspects of industrial research. It has provided assistance to individual industrial firms and to associations of firms interested in establishing or expanding their research activities. It has served as a channel whereby companies have arranged for sponsored projects to be undertaken in the Organization's laboratories. Members of the Section have prepared articles describing C.S.I.R.O. activities for publication in the technical and trade press and have given talks on such subjects to manufacturing and commercial firms and associations. The Section has also assisted in arranging the use of the Organization's patented processes by industry.

The Section attends to the many technical inquiries submitted to Head Office. Where appropriate, these inquiries are sent on to specialists, either in the Organization or elsewhere. When this is not practicable, replies are provided by the Section.

5. OVERSEAS LIAISON.

The Organization has Scientific Liaison Offices in London and Washington as constituent units of the British Commonwealth Scientific Office (London), and the British Commonwealth Scientific Office (North America). These Offices maintain close contact with overseas scientific developments and serve as centres for visitors and research students from the Organization and for other visiting scientists. The Chief Scientific Liaison Officers in London and Washington have represented Australia at scientific conferences in the United Kingdom, the United States of America, and Europe. The London Office has materially assisted in the recruitment of research staff from the United Kingdom and European countries.

6. FILM UNIT.

During the year the following films were completed and released:—

Two Blades of Grass.—16 mm., colour, sound, screening time 24 minutes. Produced in collaboration with the New South Wales Department of Agriculture and Profesor C. M. Donald of the Waite Agricultural Research Institute, South Australia, the film develops the theme that Australia's agricultural future depends on the use of a properly fertilized legume either as a component of pastures or as a rotation in agricultural cropping.

The Mutton Birds of Bass Strait—16 mm., colour, sound, screening time 21 minutes. Produced in collaboration with the Wildlife Survey Section, the film covers the interesting habits and life history of a species of mutton bird (*Puffinus tenuirostris*), the industry based on the annual harvest of the fledglings, and the conservation studies and allied research being undertaken by the Wildlife Survey Section in co-operation with the Fauna Board of Tasmania.

The Argentine Ant—16 mm., colour, sound, screening time 11½ minutes. This film, first released in 1953, has been re-edited to include reference to a more recently developed insecticide which is more persistent and most effective in the eradication of the Argentine ant.

Films on the following subjects are in the course of production:—

Supply and Drainage Ditches—16 mm., colour, sound.

The Penguins of Macquarie Island—16 mm., colour, sound.

The Construction of Farm Dams—16 mm., colour, sound.

Radio Astronomy in Australia—16 mm., colour, sound.

Mitosis—16 mm., colour, sound.

Pruning of Grape Vines—16 mm., colour, sound.

The Mallee Fowl—16 mm., colour, sound.

Two short films are being produced for the Australian National Antarctic Research Expedition, from original film material already obtained.

Cine film records have been continued of cattle breeding experiments being conducted by the Division of Animal Health and Production at "Belmont" Field Station and elsewhere in Australia.

The United States Department of Agriculture is having 30 prints of the film "Bovine Contagious Pleuropneumonia" made for distribution throughout the United States.

Excluding the above, 87 prints of the Unit's films have been distributed during the year. Most of these have been puchased by outside organizations.

In spite of the wide distribution of the Unit's films, particularly in Australia, 330 film loans were made during the year through the Organization's own film library.

XXXIII. PERSONNEL OF COUNCIL AND COMMITTEES.

1. Executive.

Sir Ian Clunies Ross, C.M.G., D.V.Sc., LL.D., F.A.A. (*Chairman*).

F. W. G. White, C.B.E., M.Sc., Ph.D. (*Chief Executive Officer*).

S. H. Bastow, D.S.O., B.Sc., Ph.D.

H. J. Goodes, O.B.E., B.A.

A. W. Coles.

2. Advisory Council.

Chairman.

Sir Ian Clunies Ross, C.M.G., D.V.Sc., LL.D., F.A.A.

Executive.

(*See above.*)

Chairmen of State Committees.

New South Wales—Professor H. R. Carne, D.V.Sc.
Victoria—Professor J. S. Turner, M.A., Ph.D., M.Sc., F.A.A.
Queensland—Professor W. V. Macfarlane, M.A., M.D.
South Australia—A. R. Callaghan, C.M.G., D.Phil., B.Sc., B.Sc.Agr.
Western Australia—Professor N. S. Bayliss, B.A., B.Sc., Ph.D., F.A.A.
Tasmania—T. A. Frankcomb.

Co-opted Members.

L. B. Bull, C.B.E., D.V.Sc., F.A.A.
The Hon. O. McL. Falkiner, M.L.C.
W. A. Gunn, C.M.G.
D. R. Hawkes.
A. McCulloch, M.E.
D. Mackinnon.
I. M. McLennan, B.E.E.
Professor L. H. Martin, C.B.E., Ph.D., F.A.A.
M. A. Mawby, D.Sc., F.S.T.C., F.A.A.
Professor M. L. Oliphant, M.A., Ph.D., D.Sc., LL.D., F.A.A., F.R.S.
W. W. Pettingell, B.Sc.
A. B. Ritchie, M.A.
W. J. Russell, A.C.I.A.
E. M. Schroder.
H. B. Somerset, M.Sc.
Professor A. D. Trendall, M.A., Litt.D.
J. V. Vernon, B.Sc., Ph.D.

3. State Committees.

New South Wales.

Professor H. R. Carne, D.V.Sc. (*Chairman*).
Emeritus Professor Sir Henry Barraclough, K.B.E., V.D., B.E., M.M.E.
Professor J. P. Baxter, O.B.E., B.Sc., Ph.D., F.A.A.
F. S. Bradhurst, D.Sc.
V. J. F. Brain, B.E.
J. N. Briton, B.Sc., B.E.
S. F. Cochran, F.A.S.A.
The Hon. O. McL. Falkiner, M.L.C.
W. R. Hebblewhite, B.E.
E. L. S. Hudson, Dip.For.
The Hon. Sir Norman Kater, M.L.C., M.B., Ch.M.
J. F. Litchfield.
Professor P. R. McMahon, M.Agr.Sc., Ph.D.
Professor J. R. A. McMillan, D.Sc.Agr., M.S.
Emeritus Professor Sir John Madsen, B.E., D.Sc., F.A.A.
J. Merrett.
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XXXIV. STAFF.

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Technical Officer—Miss J. Quiggan, B.Sc.Agr.
Technical Officer—Miss M. E. Singer, B.Sc.
Technical Officer—S. S. Y. Young, B.Agr.Sc.
Librarian—Miss S. J. Hicks.

At Regional Pastoral Laboratory, Armidale, New South Wales—
Executive Officer to Research Committee—J. F. Barrett, B.V.Sc.
Senior Research Officer—W. H. Southcott, B.V.Sc.
Senior Technical Officer—R. W. Hewetson, B.V.Sc.
Technical Officer—J. M. George, B.Sc.Agr.

At F.D. McMaster Field Station, Badgery's Creek, New South Wales—
Officer-in-Charge—R. H. Hayman, M.Agr.Sc.
Research Officer—J. M. Doney, B.Sc. (Hons.), Ph.D.
Research Officer—D. F. Dowling, B.V.Sc., B.Sc., Ph.D.

At Veterinary Parasitology Laboratory, Yeerongpilly, Queensland—
Officer-in-Charge—Dr. F. H. S. Roberts, D.Sc. (overseas).
Senior Research Officer and Acting Officer-in-Charge—R. F. Riek, B.V.Sc., M.Sc.
Senior Research Officer—P. H. Durie, M.Sc.
Research Officer—K. C. Bremner, M.Sc.
Technical Officer—R. K. Keith, Dip.Ind.Chem.

At Department of Physiology, University of Queensland, Brisbane—
Senior Research Officer—N. T. M. Yeates, B.Agr.Sc. (Hons.), Ph.D.

At National Field Station, "Gilruth Plains", Cunnamulla, Queensland—
Officer-in-charge—C. H. S. Dolling, B.Ag.Sc., R.D.A.

At National Cattle Breeding Station, "Belmont", Rockhampton, Queensland—
Officer-in-charge—J. F. Kennedy, M.Agr.Sc.
Senior Research Officer—H. G. Turner, B.Agr.Sc., M.A.
Technical Officer—A. V. Schleger, B.Sc.
Technical Officer—G. French, B.V.Sc.

At Western Australian Department of Agriculture, Animal Health and Nutrition Laboratory, Nedlands, Western Australia—
Senior Research Officer—A. B. Beck, M.Sc.

At Institute of Agriculture, University of Western Australia, Nedlands, Western Australia—
Senior Research Officer—E. Munch-Petersen, M.Sc., B.A.

At Department of Genetics, University of Adelaide, Adelaide, South Australia—
Research Officer—G. W. Grigg, M.Sc., Ph.D.

6. DIVISION OF BIOCHEMISTRY AND GENERAL NUTRITION.

(Head-quarters: University of Adelaide.)

Chief—H. R. Marston, F.A.A., F.R.S.
Technical Secretary—A. Packham, B.V.Sc.
Principal Research Officer—Miss M. C. Dawbarn, M.Sc.
Principal Research Officer—F. V. Gray, M.Sc.
Principal Research Officer—I. G. Jarrett, M.Sc.
Principal Research Officer—H. J. Lee, M.Sc.
Principal Research Officer—J. A. Mills, Ph.D., M.Sc.
Principal Research Officer—A. W. Peirce, D.Sc.
Principal Research Officer—D. S. Riceman, M.Sc., B.Ag.Sc.
Senior Research Officer—Miss S. H. Allen, B.Sc.
Senior Research Officer—G. B. Jones, M.Sc.
Senior Research Officer—A. F. Pilgrim, B.Sc.
Research Officer—W. W. Forrest, B.Sc. (Hons.), Ph.D.
Research Officer—J. L. Frahn, Ph.D., M.Sc.
Research Officer—R. E. Kuchel, B.Sc.
Research Officer—B. J. Potter, M.Sc.
Research Officer—Mrs. D. C. Roder, M.Sc.
Research Officer—R. M. Smith, B.Sc.
Research Officer—R. A. Weller, B.Sc.
Principal Technical Officer—D. W. Dewey.
Senior Technical Officer—R. Hewett Jones, R.D.A.
Senior Technical Officer—V. A. Stephen.
Technical Officer—A. C. Blaskett, B.Sc.
Technical Officer—J. Charnock, B.Sc.
Technical Officer—O. H. Filsell, B.Sc.
Technical Officer—B. F. Good, B.Sc.
Technical Officer—W. S. Osborne-White, B.Sc.
Technical Officer—J. O. Wilson (part-time).

7. DIVISION OF BUILDING RESEARCH.

(Head-quarters: Graham-road, Highett, Victoria.)

Administration—
Chief—Ian Langlands, M.Mech.E., B.E.E.
Technical Secretary—J. R. Barned, B.Sc. (Hons.).
Editor—I. C. H. Croll, B.Sc.
Sectional Draughtsman—W. Maier, Dip.Ing.

Information and Library—
Senior Research Officer—R. C. McTaggart, B.Sc.
Senior Technical Officer—E. McC. Coulter, M.Ag.Sc.

Concrete and Testing Laboratory—
Senior Research Officer—F. A. Blakey, B.E., Ph.D.
Principal Technical Officer—W. H. Taylor, M.C.E.
Senior Technical Officer—R. E. Lewis, B.Sc. (Hons.).
Senior Technical Officer—E. N. Mattison.
Technical Officer—B. Kroone, D.R.S.
Technical Officer—F. D. Beresford, F.R.M.T.C.
Technical Officer—J. J. Russell, B.Sc.

Masonry Investigations—
Principal Research Officer—J. S. Hosking, M.Sc., Ph.D.
Principal Research Officer—W. F. Cole, M.Sc., Ph.D.
Senior Research Officer—H. V. Hueber, Dr.Phil.
Senior Research Officer—R. D. Hill, B.Sc. (Hons.), B.Com.
Research Officer—Mrs. T. Demediuk, Dr.Phil.Nat.
Research Officer—Miss A. A. Milne, B.Sc. (Hons.), Ph.D.
Technical Officer—Miss M. E. Neilson, B.Sc.
Technical Officer—Miss N. M. Rowland, F.R.M.T.C.
Technical Officer—A. E. Holland, A.R.M.T.C.
Technical Officer—D. N. Crook, A.Sw.T.C.
Technical Officer—C. L. Carrel, B.Sc. (Hons.).

Surfacing Materials Investigations—
Senior Research Officer—E. H. Waters, M.Sc.
Research Officer—J. E. Bright, B.Sc.
Technical Officer—D. A. Powell, B.Sc.
Technical Officer—G. F. Moss, B.Sc.
Technical Officer—I. D. McLachlan, A.S.M.B.

Acoustics and Thermal Investigations—
Principal Research Officer—R. W. Muncey, B.Eng.Sc., M.E.E.
Senior Research Officer—W. K. R. Lippert, Dr. rer.nat.
Senior Research Officer—A. F. B. Nickson, M.Sc.
Research Officer—T. S. Holden, B.Sc.
Technical Officer—P. Dubout, B.Sc.
Technical Officer—Miss A. Greenslade, B.Arch. (Hons.).

Organic Materials Investigations—
Senior Research Officer—E. R. Ballantyne, B.Sc. (Hons.).
Research Officer—K. G. Martin, B.Sc. (Hons.).
Technical Officer—J. W. Spencer, B.Sc.
Technical Officer—N. G. Brown, A.R.M.T.C.

8. CANBERRA LABORATORIES, ADMINISTRATIVE OFFICE.

(The services of this office are common to the Divisions and Sections in Canberra.)

Chief Clerk—K. J. Prowse.
Deputy Chief Clerk—D. Banyard.
Accountant—E. E. Petersen.
Librarian—D. R. May, B.A., B.Sc.

9. COAL RESEARCH SECTION.

(Head-quarters: Delhi-road, North Ryde, New South Wales.)

Officer-in-charge—H. R. Brown, B.Sc. (Eng.) (Hons.).
Technical Secretary—K. F. Baker, M.Sc. App., D.Sc. Tech.

Principal Research Officer—J. D. Brooks, B.Sc. (Hons.).
Principal Research Officer—N. Y. Kirov, M.Sc.
Senior Research Officer—B. E. Balme, B.Sc. (Hons.).
Senior Research Officer—R. A. Durie, M.Sc., Ph.D.
Senior Research Officer—E. J. Greenhow, B.Sc., (Hons.), Ph.D.
Senior Research Officer—A. Jowett, B.Sc. (Hons.), Ph.D.
Senior Research Officer—P. L. Waters, B.Sc. (Hons.), Ph.D.
Research Officer—J. J. Batten, M.Sc. (on overseas studentship).
Research Officer—M. Kossenberg, Ph.D.
Research Officer—J. S. Shannon, B.Sc. (Hons.), Ph.d
Research Officer—J. F. Stephens, M.Sc. (on overseas studentship).
Research Officer—S. Sternhell, M.Sc.
Research Officer—G. H. Taylor, M.Sc., Dr. rer.nat.
Principal Technical Officer—M. S. Burns, M.Inst.F.
Senior Technical Officer—G. à Donau Szpindler, D.I.C.
Senior Technical Officer—J. P. F. Hennelly, B.Sc.
Senior Technical Officer—R. H. Jones, B.Sc. (Hons.).
Senior Technical Officer—J. W. Smith, A.R.I.C.
Senior Technical Officer—J. W. Sweeting, B.Sc.
Senior Technical Officer—J. Szewczyk, Dipl. Ing. Chem.
Technical Officer—P. R. C. Goard, B.Sc.
Technical Officer—Miss R. E. Lack, B.Sc.
Technical Officer—R. P. McDonald, M.Sc.
Technical Officer—Miss A. McI. Murray, B.Sc.
Technical Officer—R. J. Neronowicz, Dipl. Eng.
Technical Officer—D. H. Philipp, A.S.T.C.
Technical Officer—H. N. S. Schafer, B.Sc. (Hons.).
Technical Officer—W. O. Stacy, B.Sc.
Technical Officer—J. N. Stephens, M.A.
Technical Officer—A. Watts, A.S.M.B.
Technical Officer—Mrs. P. White, B.Sc.
Librarian—Mrs. R. Watkinson, B.Sc.

10. Dairy Research Section.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—G. Loftus Hills, B.Agr.Sc.
Laboratory Secretary—A. K. Klingender, B.Sc.
Principal Research Officer—N. King, M.Sc.
Senior Research Officer—E. G. Pont, M.Sc.Agr.
Senior Research Officer—K. Kumetat, Dr. Phil.
Senior Research Officer—J. Conochie, B.Sc. (Agric.).
Senior Research Officer—J. Czulak, B.Sc. (Agric.), Dip. Bact.
Research Officer—D. A. Forss, M.Sc.
Research Officer—J. W. Lee, B.Sc. (on leave).
Research Officer—A. J. Lawrence, B.Sc.
Senior Technical Officer—Miss B. M. P. Keogh, M.Sc.
Technical Officer—R. Beeby, A.R.M.T.C.

11. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—F. J. Lehany, M.Sc.
Technical Secretary—R. C. Richardson, B.E.
Senior Principal Research Officer—W. K. Clothier, B.Sc., M.E.
Principal Research Officer—A. M. Thompson, B.Sc. (Hons.).
Principal Research Officer—R. J. Meakins, B.Sc., Ph.D.
Principal Research Officer—B. V. Hamon, B.Sc. (Hons.), B.E.
Principal Research Officer—D. L. Holloway, B.E.E., M.Eng.Sc., D.Sc.(Eng.).
Senior Research Officer—L. G. Dobbie, M.E.
Senior Research Officer—J. S. Dryden, M.Sc., Ph.D.
Senior Research Officer—J. J. O'Dwyer, B.Sc., B.E., Ph.D.
Senior Research Officer—T. M. Palmer, Dipl.F.H.
Senior Research Officer—D. L. H. Gibbings, B.E., B.Sc., Ph.D.
Senior Research Officer—D. W. Posener, M.Sc., Ph.D.
Research Officer—G. J. A. Cassidy, B.E.E.
Research Officer—H. K. Welsh, M.Sc.
Research Officer—D. G. Lampard, M.Sc., Ph.D.
Research Officer—G. J. Johnson, B.Sc. (Hons.).
Research Officer—P. G. Harper, B.Sc. (Hons.), Ph.D.
Research Officer—W. E. Smith, B.Sc. (Hons.) (studentship abroad).
Principal Technical Officer—L. Medina, Dipl.Ing.
Principal Technical Officer—L. M. Mandl, Dipl.Ing.
Senior Technical Officer—H. A. Smith, A.S.T.C.
Senior Technical Officer—F. C. Brown, A.S.T.C.
Senior Technical Officer—R. W. Archer, A.S.T.C.
Senior Technical Officer—D. B. Armitage, B.Sc., B.E.
Technical Officer—E. Cowcher, B.A., A.S.T.C. (on leave).
Technical Officer—M. C. McGregor, A.S.T.C.
Technical Officer—H. Bairnsfather.
Technical Officer—H. C. Collins, A.S.T.C.
Technical Officer—J. M. Melano, A.S.T.C.
Technical Officer—R. E. Holmes, A.S.T.C.
Technical Officer—R. P. Hoffman, A.Sw.T.C.
Technical Officer—F. C. Hawes, A.S.T.C.
Technical Officer—J. S. Cook, B.Sc.
Technical Officer—I. K. Harvey, A.S.T.C.
Technical Officer—D. A. Mustard, B.Sc. (Hons.).
Technical Officer—J. L. Goldberg, B.Sc., B.E.
Technical Officer—P. Buss, A.S.T.C.
Technical Officer—K. S. Reid, A.S.T.C.

12. Engineering Section.

(Head-quarters: Explosives Factory, Maribyrnong.)

Officer-in-charge—R. N. Morse, B.Sc., B.E.
Electrical and Mechanical Engineer—F. G. Hogg, B.E.
Senior Research Officer—J. J. Kowalczewski, Dipl.Ing.
Research Officer—M. G. Kovarik, Dipl.Ing.
Research Officer—I. P. Arthur, B.Mech.E. (on leave).
Principal Technical Officer—K. A. Robeson, B.Mech.E.
Principal Technical Officer—G. M. Rostos, Dipl.Ing.
Senior Technical Officer—J. T. Czarnecki, Dipl.Ing.
Chief Draughtsman—G. T. Stephens, Dip.Mech.Eng., Dip.Elec.Eng.
Senior Technical Officer—D. W. Cunliffe, F.R.M.T.C.
Sectional Draughtsman—W. R. Read.
Sectional Draughtsman—J. R. Mitchell, Dip.Mech.Eng., Dip.Elec.Eng.
Draughtsman, Grade II.—E. T. Davey.
Draughtsman, Grade II.—D. H. Lee.
Draughtsman, Grade II.—H. L. Chapman.
Sectional Draughtsman—C. M. Williamson (at Sydney).

13. Division of Entomology.

(Head-quarters: Canberra, Australian Capital Territory.)

At Canberra—

Administration—
Chief—A. J. Nicholson, D.Sc., F.A.A.
Assistant Chief—D. F. Waterhouse, D.Sc., F.A.A. (abroad).
Technical Secretary—K. L. Taylor, B.Sc.Agr.

Population Dynamics—
Chief of Division—A. J. Nicholson, D.Sc., F.A.A.
Senior Technical Officer—A. T. Mills.

Field Population Studies—
Principal Research Officer—L. R. Clark, M.Sc.
Technical Officer—A. Magassy, Dr.Agr.Sc.

Termite Investigations—
Principal Research Officer—F. J. Gay, B.Sc. (Hons.), D.I.C.

Locust and Grasshopper Investigations—
Principal Research Officer—K. H. L. Key, D.Sc.
Technical Officer—L. J. Chinnick, R.D.A.

Miscellaneous Grasshopper Investigations—
Research Officer—D. P. Clark, B.Sc. (Hons.), Ph.D.

Biological Control—
Principal Research Officer—F. Wilson, D.I.C.
Research Officer—G. F. Bornemissza, Ph.D.
Research Officer—Mrs. M. Carver, B.Sc. (Hons.), Ph.D.

Insecticide Investigations—
Senior Research Officer—R. W. Kerr, B.Sc.

Physiology and Toxicology—
Assistant Chief—D. F. Waterhouse, D.Sc., F.A.A. (abroad).
Principal Research Officer—D. Gilmour, M.Sc.
Senior Research Officer—R. H. Hackman, M.Sc., Ph.D.
Senior Research Officer—R. F. Powning, A.S.T.C., M.Sc.
Research Officer—L. B. Barton-Browne, B.Sc. (Hons.), Ph.D.
Research Officer—A. R. Gilby, M.Sc., Ph.D. (studentship leave).
Senior Technical Officer—H. Irzykiewicz.
Technical Officer—Mrs. M. M. Goldberg, B.Sc. (Hons.).

Taxonomy of Diptera—
Senior Research Officer—S. J. Paramonov, D.Sc.

Museum—
Research Officer—T. G. Campbell.

Virus Vector Investigations—
Principal Research Officer—M. F. Day, B.Sc. (Hons.), Ph.D., F.A.A. (seconded to A.S.L.O., Washington).
Research Officer—T. D. C. Grace, B.Sc. (Hons.).
Technical Officer—N. E. Grylls, D.D.A.

Cockchafer Investigations—
Senior Research Officer—P. B. Carne, B.Agr.Sc., Ph.D.

Ant Investigations—
Senior Research Officer—T. Greaves.

Pasture Caterpillar Investigations—
Principal Research Officer—I. F. B. Common, M.A., M.Agr.Sc.

Stored Products Pests Investigations—
Senior Research Officer—S. W. Bailey, B.Sc. (Hons.).

Potato Moth and Taxonomy of Hymenoptera—
Senior Research Officer—E. F. Riek, M.Sc.

Sheep Blowfly Ecology—
Principal Research Officer—K. R. Norris, M.Sc.

t Yeerongpilly, Queensland—
Cattle Tick Investigations—
Senior Research Officer—P. R. Wilkinson, M.A.
Senior Research Officer—W. J. Roulston, B.Sc.
Technical Officer—R. A. J. Meyers, Q.D.A.H., Q.D.D.
Technical Officer—H. J. Schnitzerling, Dip.Ind.Chem.
Technical Officer—B. F. Stone, Dip.Ind.Chem.
Technical Officer—C. A. Schuntner, B.Sc.

t Nedlands, Western Australia—
Earth Mite and Lucerne Flea Investigations—
Senior Research Officer—M. M. H. Wallace, B.Sc. (Hons.).
Technical Officer—J. A. Mahon, Dip.D.Sci.

t Sydney—
Biological Control—
Senior Research Officer—G. J. Snowball, B.Sc. (Hons.).
Technical Officer—R. G. Lukins, B.Sc.

14. DIVISION OF FISHERIES AND OCEANOGRAPHY.

(Head-quarters: Cronulla, New South Wales.)

t Cronulla—
Chief—G. F. Humphrey, M.Sc., Ph.D.
Technical Secretary—Mrs. L. M. Willings, B.A. (Hons.).
Research Fellow—L. G. M. Baas Becking, Ph.D., D.Sc.
Principal Research Officer—D. J. Rochford, B.Sc. (Hons.).
Principal Research Officer—E. J. Ferguson Wood, B.A., M.Sc.
Senior Research Officer—I. S. R. Munro, M.Sc.
Senior Research Officer—J. M. Thomson, M.Sc.
Research Officer—R. S. Spencer, B.Sc. (Hons.).
Research Officer—T. R. Cowper, B.Sc. (Hons.).
Research Officer—W. B. Malcolm, B.Sc.
Research Officer—W. Dall, M.Sc.
Research Officer—G. S. Grace, B.Sc.
Research Officer—J. P. Robins, B.Sc.
Research Officer—R. J. MacIntyre, M.Sc.
Research Officer—I. R. Kaplan, M.Sc.
Research Officer—H. B. Wiseley, M.Sc.
Technical Officer—D. J. Dunstan, B.Sc.
Technical Officer—H. R. Jitts, B.Sc.
Technical Officer—N. L. Brown, A.S.T.C.
Technical Officer—P. S. Davis, A.S.T.C.
Technical Officer—C. Walker, M. Pharm.
Technical Officer—Miss B. B. Dew, B.A.

At Melbourne—
Technical Officer—P. E. Gartner, M.C., B.Sc.

At Lakes Entrance, Victoria—
Research Officer—D. E. Kurth, M.Sc.

At Perth—
Senior Research Officer—K. Sheard, D.Sc.
Research Officer—R. G. Chittleborough, M.Sc., Ph.D.
Research Officer—R. W. George, B.Sc. (Hons.).
Technical Officer—A. Middleton, B.Sc.

At Hobart—
Senior Research Officer—A. G. Nicholls, B.Sc. (Hons.), Ph.D.
Senior Research Officer—A. M. Olsen, M.Sc.
Senior Research Officer—A. H. Weatherley, B.Sc.

At Thursday Island, Queensland—
Research Officer—J. S. Hynd, B.Sc. (Hons.).
Technical Officer—D. J. Tranter, B.Sc.

15. DIVISION OF FOOD PRESERVATION AND TRANSPORT.

(Head-quarters: State Abattoir, Homebush Bay, New South Wales.

At Homebush, New South Wales—
Administration and General—
Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Secretary—R. B. Withers, M.Sc., Dip.Ed.
Technical Officer—Miss E. M. Christie, B.Sc.
Senior Librarian—Miss B. E. Johnston, B.Sc.

Physics and Transport Section—
Senior Principal Research Officer—E. W. Hicks, B.A., B.Sc.
Senior Research Officer—M. C. Taylor, M.Sc.
Research Officer—H. L. Evans, M.Sc.
Technical Officer—J. D. Mellor.
Technical Officer—Mrs. J. A. Anet, B.Sc.

Microbiology Section—
Senior Principal Research Officer—W. J. Scott, B.Agr. Sc.
Senior Research Officer—W. G. Murrell, B.Sc.Agr., D.Phil.
Research Officer—J. H. B. Christian, B.Sc.Agr. (Hons.) (overseas).
Research Officer—R. H. Leach, M.Sc., D.Phil.
Senior Technical Officer—D. F. Ohye, D.I.C.
Technical Officer—P. R. Maguire.
Technical Officer—Miss B. J. Marshall, A.S.T.C.

Biochemistry Investigations—
Principal Research Officer—F. E. Huelin, B.Sc. (Hons.), Ph.D.
Research Officer—J. B. Davenport, M.Sc.
Technical Officer—B. H. Kennett, A.S.T.C.

Organic Chemistry Investigations—
Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil.
Research Officer—E. F. L. J. Anet, M.Sc., Ph.D.
Research Officer—D. L. Ingles, M.Sc., Ph.D.

Fruit and Vegetable Storage Section—
Senior Research Officer—E. G. Hall, B.Sc.Agr. (Hons.).
Research Officer—Miss J. M. Bain, M.Sc.
Research Officer—K. J. Scott, B.Sc.Agr., Dip.Ed. (New South Wales Department of Agriculture).
Technical Officer—T. J. Riley, H.D.A.
Technical Officer—J. B. Lee.

Canning and Fruit Products Section—
Senior Principal Research Officer—L. J. Lynch, B.Agr.Sc. (Hons.).
Principal Research Officer—J. F. Kefford, M.Sc.
Senior Research Officer—R. S. Mitchell, M.Sc.Agr.
Research Officer—B. V. Chandler, B.Sc. (Hons.).
Research Officer—E. G. Davis, B.Sc. (Hons.).
Research Officer—P. W. Board, B.Sc. (Hons.).
Research Officer—D. J. Casimir, B.Sc. (Hons.), Dip.Ed.
Technical Officer—K. A. Harper, A.S.T.C.

Dried Foods Section—
Research Officer—D. McG. McBean, B.Sc.
Technical Officer—A. A. Johnson, A.S.T.C.

Fish Preservation Investigations—
Principal Research Officer—W. A. Empey, B.V.Sc.
Technical Officer—W. A. Montgomery, A.S.T.C.

Egg Investigations—
Chief—J. R. Vickery, M.Sc., Ph.D.
Senior Technical Officer—F. S. Shenstone, A.S.T.C.

Freezing of Fruit and Vegetables—
Research Officer—S. M. Sykes, B.Sc.Agr. (New South Wales Department of Agriculture).
Research Officer—I. J. Tinsley, B.Sc., M.S. (overseas).
Research Officer—J. H. Scheltema, M.Sc.

At Auburn, New South Wales—
Meat Dehydration Investigations—
Senior Research Officer—A. R. Prater, B.Sc.Agr.
Technical Officer—F. J. Gardner, B.Sc.Agr.

At Botany School, University of Sydney—
Plant Physiology Investigations—
Chief Research Officer—R. N. Robertson, B.Sc., Ph.D., F.A.A.
Senior Research Officer—H. S. McKee, B.A., D.Phil. (overseas).
Senior Research Officer—J. F. Turner, M.Sc., Ph.D.
Research Officer—S. I. Honda, M.Sc., Ph.D.
Research Officer—Mrs. D. H. Turner, M.Sc., Ph.D.
Research Officer—A. B. Hope, B.Sc. (Hons.), Ph.D. (overseas).
Research Officer—J. D. McLean, B.Sc. (Hons.).
Technical Officer—M. D. Hatch, B.Sc. (Hons.).
Technical Officer—N. F. B. Tobin, B.Sc. (Hons.).
Technical Officer—J. Smydzuk, Ing. of Ch.

At Botany School, University of Melbourne—
Plant Physiology Investigations—
Research Officer—K. S. Rowan, M.Sc., Ph.D.

At Biochemistry School, University of Sydney—
Physical Chemistry Section—
Senior Research Officer—H. A. McKenzie, M.Sc.
Research Officer—J. J. Macfarlane, M.Sc.
Senior Technical Officer—M. B. Smith, B.Sc.
Technical Officer—Miss J. F. Back, B.Sc., Dip.Ed.

At Tasmanian Regional Laboratory, Hobart, Tasmania—
Canning and Fruit Products—
Senior Technical Officer—R. A. Gallop, A.S.T.C.

At Cannon Hill, Queensland—
Meat Investigations—
Officer-in-charge—A. Howard, M.Sc.
Senior Research Officer—G. Kaess, Dr.Ing.
Research Officer—A. D. Brown, M.Sc.
Research Officer—H. L. Webster, B.Sc., Ph.D.
Technical Officer—N. T. Russell, D.I.C.
Technical Officer—M. F. Meaney, B.Sc. (Hons.).
Technical Officer—P. E. Bouton, B.Sc.
Technical Officer—J. F. Weidemann, B.Sc.

16. DIVISION OF FOREST PRODUCTS.

(Head-quarters: 69 Yarra Bank-road, South Melbourne, Victoria.)

Administration—
Chief—S. A. Clarke, B.E.
Assistant Chief—C. S. Elliott, B.Sc. (Hons.).
Assistant Chief—H. E. Dadswell, D.Sc.
Technical Secretary—F. A. Priest, A.S.A.S.M.
Research Officer—A. P. Wymond, M.Sc.
Senior Librarian—Miss M. I. Hulme.
Librarian—Miss A. Forbes.
Principal Technical Officer—L. Santer, M.Mech.E.
Technical Officer—P. J. Moglia, Dip.Mech.Eng.

Wood and Fibre Structure Section—
Chief Research Officer-in-charge—H. E. Dadswell, D.Sc.
Principal Research Officer—A. B. Wardrop, M.Sc., Ph.D.
Senior Research Officer—Miss M. M. Chattaway, M.A., B.Sc., D.Phil.
Senior Research Officer—W. E. Hillis, M.Sc.
Senior Research Officer—H. D. Ingle, B.For.Sc.
Senior Technical Officer—C. F. James, B.Sc.
Senior Technical Officer—J. W. P. Nicholls, B.Sc.
Technical Officer—Miss M. F. Day, B.Sc. (on extended leave).
Technical Officer—Mrs. E. Scaife, B.Sc.

Wood Chemistry Section—
Senior Principal Research Officer—W. E. Cohen, D.Sc.
Principal Research Officer—D. E. Bland, M.Sc.
Principal Research Officer—H. G. Higgins, B.Sc. (Hons.)
Senior Research Officer—R. C. McK. Stewart, B.Sc.
Senior Research Officer—A. J. Watson, A.R.M.T.C.
Research Officer—Miss J. F. Hobden, B.Sc. (Hons.).
Technical Officer—Miss V. Goldsmith, A.R.M.T.C.
Technical Officer—B. Hirnyj, Dip.Eng., Dip.Chem.
Technical Officer—A. W. McKenzie, A.R.M.T.C.
Technical Officer—Miss G. Schwerin, B.Sc.

Timber Physics Section—
Principal Research Officer—R. S. T. Kingston, B.Sc., B.E.
Senior Research Officer—G. N. Christensen, M.Sc., Ph.D.
Senior Research Officer—L. N. Clarke, M.Mech.E., B.Eng.Sc.
Research Officer—Miss K. E. Kelsey, M.Sc.
Senior Technical Officer—L. D. Armstrong, A.R.M.T.C.
Senior Technical Officer—D. R. L. Callow, B.E. (Mech. and Elec.)
Senior Technical Officer—N. C. Edwards, A.S.M.B.
Senior Technical Officer—P. U. A. Grossman, M.Sc., Ph.A.Mr.

Timber Mechanics Section—
Principal Research Officer—J. D. Boyd, M.C.E.
Senior Research Officer—N. H. Kloot, M.Sc.
Senior Research Officer—R. G. Pearson, B.A., B.C.E.
Senior Technical Officer—R. N. Bournon.
Senior Technical Officer—J. J. Mack, A.R.M.T.C.
Technical Officer—Miss A. Ryan, A.R.M.T.C.
Technical Officer—K. B. Schuster, A.R.M.T.C.

imber Seasoning Section—

Senior Principal Research Officer—G. W. Wright, M.E.
Principal Research Officer—J. W. Gottstein, B.Sc.
Research Officer—W. G. Kauman, B.Sc. (Hons.).
Senior Technical Officer—L. J. Brennan.
Senior Technical Officer—G. S. Campbell.
Technical Officer—F. J. Christensen, A.R.M.T.C.
Technical Officer—A. Stashevski, Dip.For.Eng. E.T.H.
Technical Officer—R. Finighan, A.R.M.T.C.

Timber Preservation Section—

Principal Research Officer—N. Tamblyn, M.Sc. (Agric.)
Senior Research Officer—E. W. B. DaCosta, M.Agr.Sc.
Senior Research Officer—E. L. Ellwood, M.Sc. (For.), Ph.D.
Research Officer—P. Rudman, B.Sc., Ph.D., Dip. Microbiol.
Principal Technical Officer—F. A. Dale, Dip.Mech. Eng.
Senior Technical Officer—J. Beesley, M.Sc. (For.).
Senior Technical Officer—N. E. M. Walters, B.Sc. (Hons.)
Technical Officer—Miss F. J. Lloyd, B.Sc.
Technical Officer—D. F. McCarthy, A.R.M.T.C.

Timber Utilization Section—

Senior Principal Research Officer—R. F. Turnbull, B.E.
Senior Research Officer—K. F. Plomley, B.Sc. (Agric.).
Research Officer—W. M. McKenzie, B.Sc. (For.).
Senior Technical Officer—R. L. Cowling, Dip.Mech. Eng., Dip.E.E.
Senior Technical Officer—D. S. Jones, B.C.E.
Technical Officer—W. G. Keating, Dip.App.Sc.

17. DIVISION OF INDUSTRIAL CHEMISTRY.

Head-quarters: Lorimer-street, Fishermen's Bend, Victoria.

Administration—

Chief—I. W. Wark, D.Sc., Ph.D., F.A.A.
Divisional Secretary—W. E. Ewers, M.Sc.

Minerals Utilization Section—

Senior Principal Research Officer—R. G. Thomas, B.Sc.
Principal Research Officer—F. K. McTaggart, M.Sc.
Principal Research Officer—T. R. Scott, D.Sc., B.Ed.
Principal Research Officer—A. Walkley, B.A., D.Sc., Ph.D.
Principal Research Officer—A. W. Wylie, D.Sc., Ph.D.
Senior Research Officer—R. C. Croft, M.Sc.
Senior Research Officer—I. E. Newnham, M.Sc. (Hons.),
Senior Research Officer—E. S. Pilkington, A.S.T.C.
Senior Research Officer—A. D. Wadsley, M.Sc.
Research Officer—D. F. A. Koch, B.Sc. (Hons.), M.Sc.
Research Officer—D. E. Scaife, B.Sc. (Hons.)
Research Officer—A. G. Turnbull, B.Chem.Eng. (Hons.).
Research Officer—I. H. Warren, B.Sc. (Hons.), Dipl. Chem.Techn.
Senior Technical Officer—H. R. Skewes, A.R.A.C.I.
Technical Officer—Miss I. J. Bear, A.R.M.T.C.
Technical Officer—H. W. Fander, B.Sc. (Special).
Technical Officer—L. T. Rogers, A.R.M.T.C.
Technical Officer—Miss E. E. Rutherford, B.Sc.

Cement and Ceramics Section—

Principal Research Officer—A. J. Gaskin, M.Sc.
Principal Research Officer—H. E. Vivian, B.Sc. Agr.
Principal Research Officer—G. F. Walker, B.Sc. (Hons.), Ph.D.
Principal Research Officer—W. O. Williamson, B.Sc. (Hons.), Ph.D.
Senior Research Officer—S. M. Brisbane, B.A., B.Sc.
Senior Research Officer—H. Ellerton (at Bonython Research Laboratory, School of Mines, Adelaide).
Senior Research Officer—L. S. Williams, D. Phil., B.E.
Research Officer—K. M. Alexander, M.Sc., Ph.D.
Research Officer—G. M. Bruere, M.Sc.
Research Officer—J. H. Taplin, B.Sc. (Hons.).
Senior Technical Officer—C. E. S. Davis, B.Sc. (Hons.).
Senior Technical Officer—K. Grant, B.Sc. (Hons.).
Senion Technical Officer—R. R. Hughan.
Senior Technical Officer—J. H. Weymouth, B.Sc.
Senior Technical Officer—J. D. Wolfe.
Technical Officer—Miss V. Anderlini, B.Sc.
Technical Officer—P. J. Darragh, B.Sc. (Hons.).
Technical Officer—W. G. Garrett, A.R.M.T.C.
Technical Officer—F. C. Gillespie, B.Sc. (at Bonython Research Laboratory, School of Mines, Adelaide).
Technical Officer—Miss B. C. Terrell, B.Sc.
Technical Officer—J. Wardlaw, B.Sc. (Hons.).

Foundry Sands Section—

Senior Research Officer—H. A. Stephens, B.Sc. (Hons.).
Senior Technical Officer—A. N. Waterworth, A.H.T.C.
Technical Officer—P. W. Goad, A.R.M.T.C. (on study leave).

Chemical Physics Section—

Assistant Chief of Division—A. L. G. Rees, D.Sc., Ph.D., F.A.A.
Senior Principal Research Officer—A. Walsh, M.Sc.Tech.
Principal Research Officer—J. L. Farrant, M.Sc.
Principal Research Officer—A. McL. Mathieson, D.Sc., Ph.D.
Principal Research Officer—J. J. McNeill, M.Sc.
Principal Research Officer—D. A. Davies, B.Sc. (Hons.).
Principal Research Officer—J. M. Cowley, M.Sc., Ph.D.
Senior Research Officer—J. D. Morrison, B.Sc. (Hons.), Ph.D.
Senior Research Officer—A. J. C. Nicholson, M.Sc., Ph.D.
Senior Research Officer—J. B. Willis, M.Sc., Ph.D.
Senior Research Officer—J. Fridrichsons, M.Sc.
Senior Research Officer—G. R. Hercus, M.Sc., D.Phil.
Senior Research Officer—A. J. Hodge, B.Sc. (Hons.), Ph.D.
Senior Research Officer—B. Dawson, M.Sc., Ph.D.
Research Officer—C. K. Coogan, M.Sc., Ph.D.
Research Officer—A. F. Moodie, B.Sc. (Hons.).
Research Officer—A. C. Hurley, M.A., B.Sc., Ph.D. (on leave of absence).
Research Officer—J. P. Shelton, M.Sc. (seconded to A.S.L.O., London).
Research Officer—F. H. Dorman, M.A., M.Sc., Ph.D.
Research Officer—C. Billington, B.A.
Research Officer—J. O. Cope, M.Sc.
Research Officer—A. F. Beecham, B.Sc. (Hons.).
Research Officer—N. S. Ham, M.Sc., Ph.D.
Research Officer—J. C. Riviere, M.Sc., Ph.D.
Research Officer—J. V. Sullivan, M.Sc. (at University of Western Australia, Perth).

Research Officer—P. Goodman, M.Sc.
Research Officer—W. C. T. Dowell, M.Sc.
Research Officer—Miss Barbara J. Russell, M.Sc.
Senior Technical Officer—S. E. Powell.
Senior Technical Officer—G. F. H. Box.
Technical Officer—E. Chakanovskis, Dipl.Eng.
Technical Officer—D. L. Swingler, B.Sc. (Hons.).

Physical Chemistry Section—
Assistant Chief of Division—K. L. Sutherland, D.Sc., Ph.D.
Principal Research Officer—V. A. Garten, D.Sc.
Principal Research Officer—S. D. Hamann, M.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Principal Research Officer—D. E. Weiss, B.Sc.
Senior Research Officer—J. A. Barker, B.A. (Hons.), B.Sc.
Senior Research Officer—I. Brown, B.Sc. (Hons.).
Senior Research Officer—H. G. David, B.Sc. (at Department of Chemical Engineering, University of Sydney.)
Senior Research Officer—W. N. K. King, B.Sc.
Senior Research Officer—W. W. Mansfield, B.Sc. (Hons.).
Senior Research Officer—E. A. Swinton, B.Sc. (Hons.).
Senior Research Officer—M. E. Winfield, D.Sc., Ph.D.
Research Officer—A. Ewald, B.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Research Officer—T. Gabor, B.Sc. (Hons.).
Research Officer—A. R. King, B.Sc. (Hons.), Ph.D.
Research Officer—E. P. Purser, B.Sc. (Hons.).
Principal Technical Officer—L. F. Evans, D.S.M.B.
Technical Officer—K. Eppinger, B.Sc.
Technical Officer—W. Fock, B.Sc.
Technical Officer—M. Linton, B.Sc.
Technical Officer—R. McNeill, A.Sw.T.C.
Technical Officer—F. Smith, B.Sc. (Hons.).

Organic Chemistry Section—
Senior Principal Research Officer—H. H. Hatt, D.Sc., Ph.D.
Senior Principal Research Officer—J. R. Price, D.Sc., D.Phil.
Principal Research Officer—K. E. Murray, B.Sc. (Hons.).
Principal Research Officer—K. W. Zimmermann, D.Ing.
Senior Research Officer—R. B. Bradbury, B.Sc., Ph.D.
Senior Research Officer—W. D. Crow, M.Sc., Ph.D.
Senior Research Officer—C. C. J. Culvenor, Ph.D. D.Phil.
Senior Research Officer—L. K. Dalton, A.S.T.C. (on leave of absence).
Senior Research Officer—J. S. Fitzgerald, M.Sc., Ph.D.
Senior Research Officer—N. C. Hancox, M.Sc.
Research Officer—C. S. Barnes, M.Sc., Ph.D.
Research Officer—J. R. Cannon, M.Sc., Ph.D.
Research Officer—D. T. Downing, B.Sc. (Hons.), Ph.D.
Research Officer—E. Gellert, Ph.D.
Research Officer—J. A. Lamberton, B.Sc. (Hons.), Ph.D.
Research Officer—W. Segal, M.Sc., Ph.D.
Research Officer—P. C. Wailes, M.Sc., Ph.D.
Technical Officer—Miss Y. Greet, B.Sc.
Technical Officer—P. M. Hunter, A.Sw.T.C.
Technical Officer—M. Michael, M.Sc. (on study leave).
Technical Officer—A. H. Redcliffe, A.R.M.T.C.
Technical Officer—L. W. Smith, B.Sc.
Technical Officer—A. Z. Szumer, A.R.M.T.C. (on study leave).
Field Botanist—W. T. Jones (at Brisbane).

Chemical Engineering Section—
Principal Research Officer—R. W. Urie, B.Sc. (Hons.), S.M.
Senior Research Officer—T. J. Birch, Chem.Eng.
Senior Research Officer—J. D. Blackwood, M.Sc., Ph.D.
Senior Research Officer—O. G. Ingles, B.A., M.Sc.
Senior Research Officer—A. B. Whitehead, B.Sc. (Hons.).
Research Officer—K. J. Cannon, B.E., Ph.D.
Research Officer—K. R. Hall, M.Sc.
Research Officer—P. Terry, B.Sc. (Hons.), M.S. (Chem. Eng.)
Principal Technical Officer—B. W. Wilson, M.Sc.
Senior Technical Officer—A. J. Stedman, M.A.
Senior Technical Officer—D. H. Trethewey, A.R.M.T.C.
Technical Officer—P. Casamento, D.Chem.
Technical Officer—A. Dielenberg, Dip.Ing.
Technical Officer—J. D. Fock, B.A.
Technical Officer—F. McGrory, B.Sc. (Chem.Eng.), (Hons.).

Engineering Services—
Senior Technical Officer—J. B. Ross, B.Sc., A.R.M.T.C.
Sectional Draughtsman—C. Simpson.

Library—
Librarian—Miss B. M. Brown, B.Sc.

At Division of Electrotechnology, Sydney—
Research Officer—H. K. Welsh, M.Sc.

18. INDUSTRIAL RESEARCH LIAISON SECTION.

(Head-quarters: 314 Albert-street, East Melbourne.)

Officer-in-charge—L. Lewis, B.Met.E.
Senior Research Officer—J. F. H. Wright, B.Sc.
Senior Technical Officer—J. D. Dover, A.S.T.C.

19. IRRIGATION RESEARCH STATIONS.

(Head-quarters, Merbein, Victoria.)

Senior Officer-in-charge—F. Penman, M.Sc.

At Commonwealth Research Station, Merbein (Murray Irrigation Areas)—
Officer-in-charge—F. Penman, M.Sc.
Technical Secretary—D. V. Walters, M.Agr.Sc.
Principal Research Officer—J. G. Baldwin, B.Agr.Sc., B.Sc.
Senior Research Officer—R. J. L. Martin, M.Sc., Ph.D.
Research Officer—W. J. Webster, B.Sc.
Research Officer—A. J. Antcliff, B.Sc. (Hons.).
Research Officer—M. R. Sauer, B.Agr.Sc.
Research Officer—S. F. Bridley, B.Agr.Sc.
Research Officer—R. C. Woodham, B.Agr.Sc.
Research Officer—D. McE. Alexander, B.Sc.
Research Officer—M. Maasland, Ir.Agr., M.Sc.
Research Officer—J. V. Seekamp, B.Agr.Sc. (part-time).
Senior Technical Officer—J. E. Giles.
Technical Officer—S. A. Giddings, B.Sc.
Technical Officer—P. May, Ing.Agr.

At Irrigation Research Station, Griffith (Murrumbidgee Irrigation Area)—
Officer-in-charge—E. S. West, B.Sc., M.S.
Research Officer—C. T. Gates, B.Sc.Agr. (Hons.).
Research Officer—T. Talsma, Ir.Agr.
Research Officer—D. Bouma, Ir.Agr.

Research Officer—H. Groenewegen, Ir.Agr.
Research Officer—R. F. Black, B.Sc. (Hons.).
Research Officer—Mrs. J. Tully, B.Sc. (Hons.), Ph.D. (seconded to Agricultural Research Liaison Section).
Technical Officer—Miss J. Connor, B.Sc., Ph.D. (abroad).
Librarian—Miss M. Russell.

20. Land Research and Regional Survey Section.

Head-quarters: Canberra, Australian Capital Territory.)

ead-quarters—
Officer-in-charge—C. S. Christian, B.Agr.Sc., M.S.
Technical Secretary—Miss M. Mills, B.Sc. (Hons.).
Technical Officer—W. J. Curnow, B.Sc.

egional Surveys—
Principal Research Officer—G. A. Stewart, M.Agr.Sc.

Australian Mainland Survey, Canberra—
Research Officer—N. H. Speck, M.Sc.
Research Officer—W. H. Litchfield, B.Sc.Agr. (seconded from Division of Soils).
Research Officer—C. R. Twidale, M.Sc. (on study leave abroad).
Technical Officer—M. Lazarides, Q.D.A.

Papua-New Guinea Survey, Canberra—
Senior Research Officer—H. A. Haantjens, Ing.Agr.
Senior Research Officer—R. D. Hoogland, D.Sc.
Research Officer—B. W. Taylor, B.Sc.
Research Officer—E. Reiner, Dr.rer.nat.
Technical Officer—J. Saunders, B.Sc.Agr.

gricultural Research—
Principal Research Officer—E. Phillis, Ph.D., D.Sc.

At Katherine Research Station, Northern Territory—
Research Officer—W. Arndt, B.Agr.Sc.
Research Officer—M. J. T. Norman, B.Sc. (Hons.), Ph.D.
Research Officer—R. Wetselaar, Ing.Agr.
Technical Officer—L. J. Phillips, Q.D.D.M.
Technical Officer—W. R. Stern, B.Sc.Agr.

At Kimberley Research Station, Western Australia—
Research Officer—L. C. Lee, B.Agr.Sc.
Technical Officer—E. C. B. Langfield.
Technical Officer—A. L. Chapman, B.Agr.Sc.

Climatology, Canberra—
Research Officer—R. O. Slatyer, M.Sc., (Agric.).
Research Officer—J. L. Frith, B.Sc. (Agric.) (Hons.).
Research Officer—J. C. Turner, B.Sc.Agr. (Hons.).

Arid Zone Research—
Senior Research Officer—R. A. Perry, M.Sc.

At Alice Springs—
Technical Officer—R. E. Winkworth, B.Sc. (Hons.).

21. Mathematical Instruments Section.

(Head-quarters: Department of Electrical Engineering, University of Sydney.)

Officer-in-charge—Professor D. M. Myers, B.Sc., D.Sc.Eng.
Research Officer—M. W. Allen, B.E.
Technical Officer—A. V. Savory, M.I.E. (Aust.).

22. Division of Mathematical Statistics.

(Head-quarters: University of Adelaide.)

At Head-quarters, Adelaide—
Chief—E. A. Cornish, B.Agr.Sc., D.Sc., F.A.A.
Principal Research Officer—A. T. James, M.Sc., Ph.D.
Research Officer—G. N. Wilkinson, B.Sc. (Hons.).
Research Officer—G. W. Hill, M.Sc.

At Division of Animal Health and Production, Sydney—
Technical Officer—A. M. W. Verhagen, Cand.Nat.Phil. (Utrecht), B.A. (Hons.).

At Division of Animal Health and Production, Prospect, New South Wales—
Research Officer—H. Weiler, Lic.ès.Sc.(Par.).

At Division of Building Research, Highett, Victoria—
Senior Research Officer—R. Birtwistle, B.Sc.
Technical Officer—G. A. Watterson, B.A. (Hons.).

At Division of Food Preservation and Transport, Homebush, New South Wales—
Senior Research Officer—G. G. Coote, B.A., B.Sc.
Research Officer—A. G. L. Elliott, B.Sc. (Hons.).
Research Officer—A. G. Constantine, B.Sc. (Hons.).

At Division of Forest Products, Melbourne—
Principal Research Officer—E. J. Williams, B.Com., D.Sc.

At Division of Plant Industry, Canberra—
Senior Principal Research Officer—G. A. McIntyre, B.Sc. (Hons.), Dip.Ed.
Research Officer—M. L. Dudzinski, B.Sc., B.Ec. (Hons.).

At Division of Plant Industry, Brisbane—
Research Officer—K. P. Haydock, B.Sc. (Hons.).

At Regional Pastoral Laboratory, Armidale, New South Wales—
Research Officer—P. F. May, B.Sc.Agr. (Hons.).

At Western Australian Regional Laboratory, Perth—
Research Officer—N. S. Stenhouse, B.Sc.

At Wool Textile Research Laboratory, Melbourne—
Research Officer—W. B. Hall, B.A.

23. Division of Meteorological Physics.

(Head-quarters: Station-street, Aspendale, Victoria.)

Chief—C. H. B. Priestley, M.A., Sc.D., F.A.A.
Senior Principal Research Officer—W. C. Swinbank, B.Sc. (Hons.).
Principal Research Officer—E. L. Deacon, B.Sc.
Principal Research Officer—A. F. A. Berson, Dr.Phil.
Senior Research Officer—R. J. Taylor, B.Sc.
Senior Research Officer—I. C. McIlroy, B.Sc.
Research Officer—E. K. Webb, B.A. (Hons.), B.Sc.
Research Officer—A. J. Dyer, M.Sc., Ph.D.
Research Officer—F. K. Ball, B.Sc. (Hons.).
Research Officer—C. F. Barrett, M.Sc.
Senior Technical Officer—D. E. Angus, B.Sc.
Technical Officer—A. J. Troup, B.Sc.
Technical Officer—R. R. McGregor, Dip.App.Sc.
Technical Officer—D. R. Samuel, Dip.App.Phy.

24. Division of Metrology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Administration—
Chief—N. A. Esserman, B.Sc.
Technical Secretary—N. J. C. Peres, M.Sc.
Technical Officer—O. Pain.

Length Section—
Senior Research Officer—M. J. Puttock, B.Sc. (Eng.).
Research Officer—Miss M. G. I. Pearce, M.Sc.
Research Officer—E. G. Thwaite, B.Sc.
Principal Technical Officer—R. H. Furniss, A.S.T.C.
Senior Technical Officer—B. H. P. Cresswell, A.S.T.C.
Senior Technical Officer—Miss M. C. Dive, B.Sc.
Technical Officer—W. A. F. Cuninghame, B.E.
Technical Officer—Miss P. M. Yelland.
Technical Officer—J. W. Bell.
Technical Officer—P. J. Sim, B.E., B.Sc.

Mass Section—

Principal Research Officer—G. A. Bell, B.Sc.
Research Officer—I. F. Mayer, B.E., B.Sc.
Senior Technical Officer—J. W. Humphries, B.Sc.
Senior Technical Officer—Miss M. M. Douglas, B.Sc.
Technical Officer—E. Grunwald, Dip.Ing.

Interferometry Section—

Principal Research Officer—C. F. Bruce, M.Sc.
Senior Research Officer—H. J. Ritter, Dr.rer.nat. math.
Research Officer—B. S. Thornton, M.Sc.
Research Officer—P. E. Ciddor, M.Sc.
Technical Officer—R. S. Fisher, A.R.M.T.C.

Electronics Section—

Senior Research Officer—H. A. Ross, A.S.T.C.
Senior Technical Officer—G. W. Gore, B.E.

Applied Mechanics Section—

Senior Principal Research Officer—C. A. Gladman, B.Sc. (Eng.).
Senior Research Officer—J. A. Macinante, B.E.
Senior Research Officer—G. Lorenz, M.E.
Senior Technical Officer—R. Springer, Dr.Mach. Const.
Senior Technical Officer—R. J. Ellis, B.E.
Senior Technical Officer—J. Waldersee, B.Sc.
Senior Technical Officer.—D. H. Fox.
Senior Technical Officer—A. Gibson, A.S.T.C.
Senior Technical Officer—P. Albrecht, B.E.
Technical Officer—L. Cridland, B.E.
Technical Officer—K. H. Edensor, A.S.T.C.

25. MINERAGRAPHIC INVESTIGATIONS.

(Head-quarters: University of Melbourne.)

Officer-in-charge—A. B. Edwards, D.Sc., Ph.D.
Senior Research Officer—G. Baker, D.Sc.
Senior Research Officer—J. McAndrew, M.Sc., Ph.D.
Research Officer—I. M. Threadgold, B.Sc.
Research Officer—K. L. Williams, B.Sc.

26. NATIONAL STANDARDS LABORATORY.

(The services shown hereunder are common to the Divisions of Metrology, Electrotechnology, and Physics, housed in the Laboratory.)

Clerical—

Chief Clerk—W. J. Gillespie, F.A.S.A., A.C.I.S., J.P.
Accountant—F. J. Whitty.

Library—

Senior Librarian—Miss M. McKechnie, B.A.
Librarian—Miss J. M. Cook, B.A.
Librarian—Miss P. M. Callaghan, B.Sc.
Librarian—Mrs. M. P. Fowler.
Librarian—Miss P. I. Ross, B.A.

Workshops—

Principal Technical Officer—J. Hanna.

Drawing Office—

Chief Draughtsman—J. Coles.
Sectional Draughtsman—I. A. Rey, A.M.I.E., I.E.E. (Eng.).
Draughtsman, Grade II.—R. Partridge.
Draughtsman, Grade II.—J. Weir.
Draughtsman, Grade II.—J. W. Stephenson.
Draughtsman, Grade II.—T. H. Gruetzmacher.
Draughtsman, Grade II.—E. Emanuel.
Draughtsman, Grade II.—R. J. Taylor.

27. OENOLOGICAL RESEARCH.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

Officer-in-charge—J. C. M. Fornachon, M.Sc., B.Ag.Sc.
Research Officer—B. C. Rankine, M.Sc.

28. ORE-DRESSING INVESTIGATIONS.

(Head-quarters: University of Melbourne.)

Officer-in-charge—Associate Professor H. H. Dunkin, B.Met.E.
Principal Research Officer—K. S. Blaskett, B.E.
Research Officer—S. B. Hudson, M.Sc.
Research Officer—J. T. Woodcock, B.Met.E., M.Eng.Sc.
Senior Technical Officer—F. D. Drews.
Technical Officer—W. J. Trahar, B.Sc.
Technical Officer—D. H. Parkhurst, A.R.M.T.C.

29. PHYSICAL METALLURGY SECTION.

(Head-quarters: University of Melbourne.)

Officer-in-charge—Professor H. W. Worner, D.Sc.
Senior Research Officer—R. C. Gifkins, B.Sc.
Research Officer—D. R. Miller, M.Sc.
Research Officer—J. W. Suiter, M.Sc.
Senior Technical Officer—J. A. Corbett.

30. DIVISIONS OF PHYSICS.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Administration—

Chief—Dr. G. H. Briggs, D.Sc., Ph.D.
Laboratory Secretary—A. G. Driver, B.Sc.

Heat—

Principal Research Officer—A. F. A. Harper, M.Sc.
Senior Research Officer—W. R. G. Kemp., B.Sc.
Senior Research Officer—R. G. Wylie, M.Sc., Ph.D.
Senior Research Officer—P. G. Klemens, M.Sc., D.Phil.
Research Officer—W. A. Caw, B.Sc. (Hons.).
Research Officer—Miss R. Scott, B.Sc. (on leave abroad).
Research Officer—J. Middlehurst, B.Sc. (Hons.).
Research Officer—J. V. McAllan, B.Sc. (Hons.) (on leave abroad).
Technical Officer—Miss I. M. Beavis, B.Sc., Dip. Ed.
Technical Officer—T. P. Jones, B.Sc.
Technical Officer—Mrs. W. Szulmayer, Dipl.Phys.
Technical Officer—R. W. Tainsh, A.S.T.C.
Technical Officer—N. R. Hickson, B.Sc.
Technical Officer—F. A. Rocke, B.Sc.
Technical Officer—M. C. Cunningham, B.Sc.

Light—

Senior Principal Research Officer—R. G. Giovanelli, D.Sc.
Senior Research Officer—W. H. Steel, B.A. (Hons.), B.Sc. (Hons.), Dr.ès.Sc.
Research Officer—W. R. Blevin, M.Sc., Dip.Ed.
Research Officer—C. E. Coulman, M.Sc.
Senior Technical Officer—K. A. Wright, B.Sc.
Technical Officer—W. J. Brown, A.S.T.C.

Solar Physics—

Research Officer—J. T. Jefferies, M.A., B.Sc. (Hons.).
Research Officer—R. E. Loughead, M.Sc.
Research Officer—R. J. Bray, M.A., D.Phil.
Technical Officer—V. R. Burgess, A.S.T.C.
Technical Officer—M. K. McCabe, M.Sc.

Electronics—

Research Officer—A. F. Young, M.Sc.
Technical Officer—P. F. Howden, B.Sc.

31. PLANT FIBRE SECTION.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—W. L. Greenhill, M.E.
Senior Research Officer—Miss J. F. Couchman, M.Sc.
Senior Research Officer—G. W. Lanigan, M.Sc.
Research Officer—J. H. McClelland, B.Sc.
Research Officer—W. Shepherd, B.Sc., B.Agr.Sc.
Technical Officer—C. J. Brady, B.Sc.Agr.
Technical Officer—R. E. Spielrein, A.R.M.T.C.

32. DIVISION OF PLANT INDUSTRY.

(Head-quarters: Canberra, Australian Capital Territory.)

dministration—
Chief—O. H. Frankel, D.Sc., D.Agr., F.A.A., F.R.S.
Associate Chief—J. Griffiths Davies, B.Sc., Ph.D.
Assistant Chief—R. M. Moore, M.Sc.Agr.
Technical Secretary—A. Shavitsky, B.Ag.Sc. (seconded to A.S.L.O., London).
Acting Technical Secretary—J. H. E. Mackay, B.Sc.Agr.
Divisional Engineer—G. L. Brown, B.Sc. (Eng.).

Group I.—Botany and Genetics—
Leader—O. H. Frankel, D.Sc., D.Agr., F.A.A., F.R.S.
Deputy Leader—C. Barnard, D.Sc.

Genetics and Cytology, Canberra—
Senior Research Fellow—M. J. D. White, D.Sc., F.A.A.
Principal Research Officer—F. H. W. Morley, B.V.Sc., Ph.D.
Principal Research Officer—J. B. Griffing, M.S., Ph.D.
Senior Research Officer—R. D. Brock, M.Agr.Sc., Ph.D.
Research Officer—H. Daday, M.Sc.
Research Officer—C. I. Davern, M.Sc.Agr.
Research Officer—D. L. Hayman, B.Ag.Sc. (Hons.).
Research Officer—J. B. Langridge, M.Sc., Ph.D.
Research Officer—D. C. Wark, M.Agr.Sc.
Technical Officer—J. W. Peak.
Technical Officer—J. A. M. Brown, B.Sc.Agr.
Technical Officer—Miss A. Munday, B.Sc.

Structural Botany, Canberra—
Principal Research Officer—C. Barnard, D.Sc.

Herbarium, Canberra—
Senior Research Officer—Miss N. T. Burbidge, M.Sc.

Plant Introduction, Canberra—
Senior Principal Research Officer—W. Hartley, B.A., Dip.Ag.
Senior Research Officer—C. A. Neal-Smith, B.Ag.Sc.
Research Officer—H. J. Ketellapper, B.Sc., Ph.D.
Technical Officer—R. J. Williams, M.Sc.
Technical Officer—Miss D. E. Johns, B.Sc.

Plant Introduction, Western Australia—
Senior Research Officer—E. T. Bailey, B.Sc. (Hons.).

Microbiology, Canberra—
Senior Research Fellow—K. O. Muller, D.Phil.
Senior Research Officer—F. W. Hely, M.Sc.Agr., M.S.
Research Officer—F. J. Bergensen, M.Sc.
Research Officer—S. M. Bromfield, M.Agr.Sc., Ph.D.
Research Officer—Miss K. Helms, M.Sc., Ph.D.
Research Officer—I. A. M. Cruickshank, M.Sc.
Research Officer—A. H. Gibson, B.Sc.Agr. (Hons.).
Research Officer—M. Zaitlin, B.Sc., Ph.D.
Technical Officer—J. Brockwell, D.D.A.

Disease Control—
Principal Research Officer—H. R. Angell, O.B.E., B.Sc.Agr., M.S., Ph.D.

Fruit Investigations, Hobart—
Principal Research Officer—D. Martin, D.Sc.
Research Officer—T. L. Lewis, B.Sc. (Hons.)
Technical Officer—J. Cerny, Dr.Tech.Sc.

Fruit Investigations, Queensland—
Principal Research Officer—L. A. Thomas, M.Sc.

Tobacco Investigations, Canberra—
Principal Research Officer—A. V. Hill, M.Sc.Agr.
Technical Officer—M. Mandryk, B.Sc.Agr.

Group 2—Chemistry and Physiology—

General Chemistry, Canberra—
Principal Research Officer—C. H. Williams, M.Sc.
Senior Research Officer—A. Steinbergs, Nut.Chem. (Riga).
Senior Research Officer—D. J. Cosgrove, B.Sc. (Hons.), Ph.D.
Research Officer—D. J. David, M.Sc.
Technical Officer—J. R. Twine, Dip.Ind.Chem.

Soil Chemistry, Melbourne—
Senior Research Officer—L. H. P. Jones, B.Agr.Sc., Ph.D.
Technical Officer—A. F. Sherrington, A.Sw.T.C.

Plant Nutrition, Canberra—
Senior Principal Research Officer—A. J. Anderson, B.Sc.(Agric.).
Senior Research Officer—K. D. McLachlan, B.Sc. Agr., B.Comm.
Senior Research Officer—D. Spencer, B.Sc. (Hons.), Ph.D.
Research Officer—J. V. Possingham, B.Ag.Sc. (Hons.) (abroad on studentship),
Research Officer—J. F. Loneragan, B.Sc. (Hons.), Ph.D.

Plant Biochemistry and Biophysics, Canberra—
Senior Principal Research Officer—J. E. Falk, M.Sc., Ph.D.
Principal Research Officer—C. G. Greenham, M.Sc.
Senior Research Officer—P. L. Goldacre, M.Sc., Ph.D.
Senior Research Officer—R. Johanson, M.Sc.
Research Officer—C. A. Appleby, B.Sc.(Hons.).
Research Officer—N. K. Boardman, M.Sc., Ph.D.
Research Officer—W. Bottomley, B.Sc.(Hons.), Ph.D.
Research Officer—J. N. Phillips, M.Sc., Ph.D.
Research Officer—P. A. Trudinger, B.Sc., Ph.D.
Research Officer—N. A. Walker, B.Sc.(Hons.).
Senior Technical Officer—P. I. Mortimer, B.Sc.
Technical Officer—P. Macnicol, B.Sc.

Plant Physiology, Canberra—
Principal Research Officer—L. A. T. Ballard, M.A., M.Agr.Sc., Ph.D.
Senior Research Officer—A. H. C. G. Rijven, B.Sc., Ph.D.
Research Officer—L. T. Evans, B.Sc., M.Agr.Sc., D.Phil.
Research Officer—N. P. Kefford, M.Sc., Ph.D.
Research Officer—J. A. Zwar, M.Agr.Sc.

Crop Physiology, Canberra—
Principal Research Officer—R. F. Williams, M.Sc.

Group 3—Ecology and Agronomy, Southern Australia—
Leader—R. M. Moore, M.Sc.Agr.

At Canberra—

Ecology—
Senior Principal Research Officer—R. M. Moore, M.Sc.Agr.
Senior Research Officer—C. W. E. Moore, M.Agr. Sc.
Senior Research Officer—E. F. Biddiscombe, M.Agr. Sc.
Research Officer—L. F. Myers, M.Agr.Sc.
Research Officer—G. Scurfield, B.Sc., Ph.D.
Technical Officer—J. A. Robertson, Q.D.D.M.

Arid Zone Ecology—
Senior Research Officer—R. W. Jessup, M.Sc.

Alpine Ecology—
Senior Research Officer—A. B. Costin, M.Sc.Agr.

Agronomy—

Senior Research Officer—W. D. Andrew, M.Agr.Sc.
Senior Research Officer—W. M. Willoughby, B.Sc. Agr.
Research Officer—R. S. J. Lipsett, B.Agr.Sc.(Hons.).
Research Officer—H. L. Davies, B.Sc.(Agr.) (Hons.).
Technical Officer—W. Straatmans, Dip.Ag., Dip. Trop.Agr.
Technical Officer—J. D. Williams, D.D.A.

Dickson Experiment Station—

Senior Technical Officer—R. J. Hutchings, D.D.A.

At Regional Pastoral Laboratory, Armidale—

Pastures—

Principal Research Officer—R. Roe, B.Sc.(Agric.).
Senior Research Officer—E. J. Hilder, B.Sc.(Agric.).
Research Officer—J. E. Begg, B.Sc.Agr.(Hons.).
Technical Officer—V. J. Wolfe, Q.D.A.
Technical Officer—B. E. Mottershead, B.Sc.
Technical Officer—J. A. Thompson, B.Sc(For.).

Plant Nutrition—

Senior Research Officer—K. Spencer, B.Sc.Agr. (Hons.) (abroad).
Technical Officer—N. J. Barrow, B.Agr.Sc.

Chemical Investigations—

Technical Officer—J. R. Freney, B.Sc.

At Regional Pastoral Laboratory, Deniliquin, New South Wales—

Officer-in-charge—R. W. Prunster, B.Sc.(Agric.).

Ecology—

Research Officer—O. B. Williams, M.Agr.Sc.

Agricultural Physics—

Principal Research Officer—D. A. de Vries, D.Sc.
Research Officer—J. R. Philip, B.C.E.

Chemistry—

Technical Officer—R. J. Hunter, B.Sc.

Agronomy—

Research Officer—J. L. Davidson, M.Agr.Sc.

Genetics—

Technical Officer—Miss V. E. Rogers, B.A.

At Mitchell Laboratory, Trangie, New South Wales—

Research Officer—A. A. Holland, M.Sc.Agr.

At Irrigation Research Station, Griffith, New South Wales—

Research Officer—E. Levi, M.Sc. (overseas).

At University of Queensland, Brisbane—

Ecology—

Senior Research Officer—L. J. Webb, M.Sc.

At Waite Agricultural Research Institute, Adelaide, South Australia—

Oil Crop Investigations—

Technical Officer—C. R. Kleinig, B.Ag.Sc.(Hons.).

At Botany Department, University of Adelaide—

Tobacco Investigations—

Research Officer—W. J. Lovett, B.Agr.Sc.

At Regional Laboratory, Perth, Western Australia—

Agronomy—

Principal Research Officer—R. C. Rossiter, D.Sc. (Agric.).
Research Officer—A. W. Humphries, B.Sc.Agric. (Hons.).
Technical Officer—R. J. Pack, Q.D.A.

Plant Nutrition—

Research Officer—P. G. Ozanne, B.Sc.Agric. (on studentship abroad).
Technical Officer—D. J. Kirton, B.Sc.(Agric.).

Chemistry—

Technical Officer—T. Shaw, B.Sc.

At "Glen Lossie" Field Station, Kojonup, Western Australia—

Senior Research Officer—E. R. Watson, M.Sc. (Agric.).
Technical Officer—P. Lapins, M.Agr.Sc.

Group 4—Agrostology and Agronomy, Queensland—

Leader—J. Griffiths Davies, B.Sc., Ph.D.
Laboratory Secretary—A. G. A. Eyles, B.Sc. (Agric.).

Agrostology—

Principal Research Officer—T. B. Paltridge, B.Sc. (Hons.) (seconded to Coconut Research Institute —Ceylon).

Agronomy—

Principal Research Officer—W. W. Bryan, M.Agr.Sc.

Regional Trials—

Research Officer—L. A. Edye, B.Ag.Sc. (Hons.).

Cattle Pastures—

Senior Research Officer—N. H. Shaw, B.Sc.Agr. (Hons.).
Research Officer—O. T. Denmead, B.Agr.Sc.(Hons.).
Technical Officer—T. W. Elich, Dip.Col.Agr.

Plant Nutrition—

Senior Research Officer—C. S. Andrew, B.Agr.Sc., B.Sc.(Hons.).
Research Officer—R. G. Coleman, B.Sc.(Agr.), Ph.D.
Research Officer—E. F. Henzell, B.Agr.Sc.(Hons.), D.Phil.
Technical Officer—W. H. J. Pieters, Dip.Col.Agr.

Plant Chemistry—

Research Officer—M. P. Hegarty, M.Sc., Ph.D.
Technical Officer—Miss P. M. Thorne, B.Sc.

Ecology—

Senior Research Officer—J. E. Coaldrake, M.Sc.
Technical Officer—W. F. Ridley, B.Sc.

Genetics—

Principal Research Officer—E. M. Hutton, B.Agr.Sc., D.Sc.

Legume Bacteriology—

Principal Research Officer—D. O. Norris, D.Sc. (Agr.).

Plant Introduction—

Principal Research Officer—J. F. Miles, M.Agr.Sc.
Research Officer—E. H. Kipps, B.Sc.

At Cooper Laboratory, Lawes, Queensland—

Senior Technical Officer—R. Milford, B.Ag.Sc.
Technical Officer—H. Kiers, Dip.Col.Agr.

33. DIVISION OF RADIOPHYSICS.

(Head-quarters: University Grounds, Sydney.)

Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D.
Assistant Chief—J. L. Pawsey, M.Sc., Ph.D., F.A.A., F.R.S.
Technical Secretary—A. J. Higgs, B.Sc.(Hons.).
Assistant Technical Secretary—L. L. McCready, B.Sc., B.E.

Cloud and Rain Physics—

Principal Research Officer—J. Warner, B.Sc., B.E.
Principal Research Officer—P. Squires, M.A.
Principal Research Officer—E. J. Smith, M.B.E., B.Sc.(Eng.)(Hons.).
Research Officer—E. K. Bigg, M.Sc., Ph.D.
Research Officer—N. R. Labrum, B.Sc.(Hons.).
Research Officer—A. A. Weiss, B.Sc.(Hons.), Ph.D.
Research Officer—E. E. Adderley, B.Sc.
Research Officer—S. Twomey, M.Sc., Ph.D.
Research Officer—J. W. Telford, B.Sc.(Hons.).
Senior Technical Officer—P. T. Hedges, A.S.T.C.
Senior Technical Officer—K. J. Heffernan.

adio Astronomy—
Visiting Research Fellow—R. Q. Twiss, M.A. (Cantab.), Sc.D.
Senior Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Principal Research Officer—W. N. Christiansen, D.Sc.
Principal Research Officer—B. Y. Mills, B.Sc., M.E.
Senior Research Officer—F. J. Kerr, M.Sc., M.A.
Senior Research Officer—C. A. Shain, B.Sc.(Hons.).
Senior Research Officer—S. F. Smerd, B.Sc.(Hons.).
Senior Research Officer—G. A. Day.
Research Officer—J. A. Roberts, M.Sc., Ph.D.
Research Officer—R. X. McGee, B.Sc.(Hons.).
Research Officer—J. A. Warburton, B.Sc.(Hons.).
Research Officer—C. S. Gum, M.Sc., Ph.D.
Research Officer—E. R. Hill, M.Sc.
Research Officer—A. G. Little, B.Sc.
Research Officer—A. W. L. Carter, B.Sc.(Hons.).
Research Officer—R. F. Mullaly, M.Sc., Ph.D.
Research Officer—D. S. Mathewson, M.Sc.
Senior Technical Officer—K. V. Sheridan, B.Sc.
Senior Technical Officer—K. R. McAlister, A.S.T.C.
Senior Technical Officer—J. V. Hindman.
Senior Technical Officer—J. D. Murray, B.Sc.(Eng.)
Senior Technical Officer—O. B. Slee, B.Sc.
Technical Officer—M. M. Komesaroff, B.Sc.
Technical Officer—K. G. Weir, A.S.T.C.

Radio Communications—
Research Officer—D. E. Yabsley, B.Sc., B.E.
Research Officer—F. F. Gardner, B.Sc., B.E., Ph.D.

Radio Navigation—
Principal Research Officer—M. Beard, B.Sc., B.E.
Technical Officer—G. A. Chandler, A.S.T.C.

Semi-conductors and Transistors—
Senior Research Officer—B. F. C. Cooper, B.Sc. (Hons.), B.E.
Senior Research Officer—L. W. Davies, B.Sc. (Hons.), D.Phil.
Research Officer—R. D. Ryan, B.Sc.(Hons.), B.E.
Research Officer—N. H. Fletcher, B.Sc., M.A., Ph.D.
Senior Technical Officer—F. C. Tonking, A.S.T.C.
Technical Officer—B. M. Bartlett, B.Sc.

Mathematical Computation—
Principal Research Officer—T. Pearcey, B.Sc.(Hons.).
Technical Officer—R. T. H. Bowles, A.R.M.T.C.

Test Room—
Senior Technical Officer—G. A. Wells, A.S.T.C.
Technical Officer—T. E. Cousins, A.S.T.C.

Engineering Services—
Chief Draughtsman—F. M. Carter.
Draughtsman, Grade II.—H. F. Peddie, A.S.T.C.
Draughtsman, Grade II.—J. R. Morris.
Draughtsman, Grade II.—R. S. Fieldgate.
Draughtsman, Grade II.—R. Kenna.

Officers Abroad—
Principal Research Officer—J. G. Bolton, B.A.
Principal Research Officer—H. C. Minnett, B.Sc., B.E.
Senior Research Officer—R. N. Bracewell, B.Sc., B.E., Ph.D.
Senior Research Officer—J. P. Wild, M.A.
Research Officer—J. S. Turner, M.Sc.
Senior Technical Officer—G. J. Stanley, A.S.T.C.

34. RADIO RESEARCH LABORATORIES.

(Head-quarters: Harben Vale, Camden, New South Wales.)

Chief Research Officer—D. F. Martyn, D.Sc., Ph.D., A.R.C.S., F.A.A., F.R.S.
Senior Principal Research Officer—G. H. Munro, D.Sc.
Senior Research Officer—W. L. Price, B.Sc. (part-time).
Research Officer—J. A. Harvey, B.Sc.
Research Officer—R. A. Duncan, B.Sc.
Technical Officer—L. H. Heisler, B.Sc.
Technical Officer—R. B. White, B.E.

35. DIVISION OF SOILS.

(Head-quarters: Waite Agricultural Research Institute, Adelaide, South Australia.)

At Adelaide—

Administration—
Chief—J. K. Taylor, B.A., M.Sc., B.Sc.Agr.
Senior Clerical Officer—F. W. Blanksby.

Soil Survey and Pedology Section—
Senior Principal Research Officer—C. G. Stephens, D.Sc.
Senior Research Officer—K. H. Northcote, B.Ag.Sc.
Senior Research Officer—G. Blackburn, B.Ag.Sc.
Research Officer—E. A. Jackson, B.Ag.Sc.
Research Officer—C. B. Wells, B.Ag.Sc.
Research Officer—C. J. de Mooy (Ing.Agr.).
Sectional Draughtsman—P. D. Hooper.

Soil Chemistry Section—
Principal Chemist—C. S. Piper, D.Sc.
Principal Research Officer—A. C. Oertel, M.Sc.
Senior Research Officer—J. T. Hutton, B.Sc.
Senior Research Officer—H. C. T. Stace, M.Sc.
Research Officer—B. M. Tucker, B.Sc.(Hons.).
Research Officer—M. Raupach, M.Sc.
Technical Officer—K. G. Tiller, B.Sc.(Hons.).
Technical Officer—M. P. C. de Vries (Ing.Agr.).
Technical Officer—A. R. P. Clarke, A.S.A.S.M.
Technical Officer—R. M. McKenzie, A.S.A.S.M.
Technical Officer—R. D. Bond, A.S.A.S.M.

Soil Physics Section—
Senior Principal Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Senior Research Officer—J. P. Quirk, B.Sc.Agr., Ph.D.
Research Officer—J. W. Holmes, M.Sc.
Research Officer—C. G. Gurr, B.Sc.
Research Officer—E. L. Greacen, B.Sc.Agr., Ph.D.

Soil Microbiology Section—
Senior Principal Research Officer—R. J. Swaby, M.Sc., M.Ag.Sc., Ph.D.
Research Officer—J. R. Harris, M.Sc.
Research Officer—J. N. Ladd, M.Sc.
Research Officer—A. D. Rovira, B.Agr.Sc.
Technical Officer—Miss J. I. Sperber, B.Sc.

Soil Mechanics Section—
Principal Research Officer—G. D. Aitchison, M.E. (at University of Melbourne).
Research Officer—I. B. Donald, B.C.E. (at University of Melbourne).

Soil Mineralogy Section—
Senior Research Officer—K. Norrish, M.Sc., Ph.D.
Research Officer—E. W. Radoslovich, M.Sc., Ph.D.
Research Officer—Mrs. L. E. R. Rogers, M.Sc.

At Brisbane—

Soil Survey and Pedology Section—
Principal Research Officer—G. D. Hubble, B.Ag.Sc.
Research Officer—G. G. Beckmann, B.Sc.
Research Officer—W. H. Litchfield, B.Sc.Agr.
Technical Officer—C. H. Thompson, Q.D.A.

Soil Physics Section—
Research Officer—G. B. Stirk, B.Sc.
Technical Officer—R. E. Prebble, B.Sc.

Soil Chemistry Section—
Senior Research Officer—A. E. Martin, B.Sc.
Research Officer—R. S. Beckwith, B.Sc. (Hons.).
Technical Officer—R Reeve, Dip.Ind. Chem.
Technical Officer—Miss J. Richardson, B.Sc.

At Canberra—

Soil Survey and Pedology Section—

Principal Research Officer—B. E. Butler, B.Sc. (Agric.)
Senior Research Officer—R. Brewer, B.Sc. (Hons.).
Research Officer—D. C. van Dijk, Ing.Agr., Dr.rer.nat.
Research Officer—J. R. Sleeman, B.Agr.Sc.
Research Officer—P. H. Walker, B.Sc.Agr. (Hons.).
Research Officer—H. M. Churchward, B.Sc.Agr. (Hons.) (at Deniliquin).
Research Officer—J. A. Beattie, B.Sc.Agr. (Hons.) (at Griffith).
Technical Officer—Miss P. Green, B.Sc.

Soil Chemistry Section—

Research Fellow—A. Wild, B.Sc., Ph.D.
Senior Technical Officer—A. D. Haldane, B.Sc.
Technical Officer—H. J. Beatty, Dip.Ind.Chem.
Technical Officer—Mrs. M. R. Reid, M.Sc.

Soil Physics Section—

Research Officer—D. S. McIntyre, M.Sc. (study leave).
Technical Officer—A. V. Blackmore, B.Sc.

At Hobart—

Soil Survey and Pedology Section—

Principal Research Officer—K. D. Nicolls, B.Ag.Sc., B.Sc.
Research Officer—G. M. Dimmock, B.Sc.
Research Officer—J. Loveday, M.Ag.Sc.

Soil Chemistry Section—

Technical Officer—A. M. Graley, B.Sc.

At Perth—

Soil Survey and Pedology Section—

Research Officer—M. J. Mulcahy, B.Sc.
Research Officer—W. M. McArthur, B.Sc. (Hons.).
Technical Officer—E. Bettenay, B.Sc. (Agr.).

Soil Chemistry Section—

Research Officer—A. G. Turton, B.Sc.
Technical Officer—F. J. Hingston, B.Sc.

36. DIVISION OF TRIBOPHYSICS.

(Head-quarters: University of Melbourne.)

Chief—W. Boas, D.Ing., M.Sc., F.A.A.
Principal Research Officer—M. F. R. Mulcahy, D.Phil., M.Sc.
Senior Research Officer—L. M. Clarebrough, B.Met.E., M.Eng.Sc., Ph.D.
Senior Research Officer—A. J. Davis, B.Eng. (abroad).
Senior Research Officer—M. E. Hargreaves, Ph.D., B.Met.E.
Senior Research Officer—J. K. Mackenzie, Ph.D., B.A. (Hons.), B.Sc.
Senior Research Officer—D. Michell, B.E.E.
Senior Research Officer—A. J. W. Moore, Ph.D., B.Sc.
Senior Research Officer—G. J. Ogilvie, Ph.D., B.Met.E., M.Eng.Sc.
Senior Research Officer—M. J. Ridge, M.Sc.
Senior Research Officer—J. V. Sanders, Ph.D., B.Sc. (Hons.).
Senior Research Officer—R. G. Vines, M.Sc.
Senior Research Officer—G. W. West, B.E.E., B.Sc.
Research Officer—B. D. Cuming, Ph.D., M.Sc.
Research Officer—E. Gillam, B.Sc., M.S.
Research Officer—D. F. Klemperer, B.Sc. (Hons.), Ph.D.
Research Officer—J. F. Nicholas, B.A. (Hons.), B.Sc.
Research Officer—T. M. Sabine, M.Sc.
Research Officer—K. Schroder, Dr.rer.nat.
Research Officer—Mrs. H. M. C. Sosnowsky, Ph.D.
Research Officer—J. A. Spink, M.Sc.
Technical Officer—G. Brinson, B.Sc.
Technical Officer—F. D. A. Haig, A.R.M.T.C.
Technical Officer—E. D. Hondros, B.Sc.
Technical Officer—M. H. Loretto, B.Met. (Hons.).
Technical Officer—G. R. Perger, F.R.M.T.C.
Technical Officer—R. G. Sherwood, A.R.M.T.C.
Technical Officer—A. J. White, A.R.M.T.C.

37. WILDLIFE SURVEY SECTION.

(Head-quarters: Canberra, Australian Capital Territory.)

Officer-in-charge—F. N. Ratcliffe, B.A.
Senior Principal Research Officer—R. Carrick, B.Sc. (Hons.), Ph.D.
Sectional Secretary—F. N. Robinson, B.A.
Research Officer—A. L. Dyce, B.Sc.Agr. (Hons.).
Research Officer—B. J. G. Marlow, B.Sc. (Hons.).
Research Officer—R. Mykytowycz, B.V.M., D.V.M.
Technical Officer—I. C. R. Rowley, B.Agr.Sc.
Technical Officer—N. Turnbull, B.Sc.

At Perth, Western Australia—

Principal Research Officer—D. L. Serventy, B.Sc. (Hons.), Ph.D.
Research Officer—J. H. Calaby, Dip. App. Chem.
Research Officer—G. M. Dunnet, B.Sc. (Hons.), Ph.D.

At Woodstock, Western Australia—

Research Officer—E. H. M. Ealey, M.Sc.

At Albury, New South Wales—

Senior Research Officer—K. Myers, B.Sc. (Hons.).
Research Officer—G. W. Douglas, B.Agr.Sc.
Research Officer—W. E. Poole, B.Sc. (Hons.).

At Griffith, New South Wales—

Senior Research Officer—H. J. Frith, B.Sc.Agr.

At Armidale, New South Wales—

Senior Research Officer—B. V. Fennessy, B.Agr.Sc.
Senior Technical Officer—E. J. Waterhouse, B.Sc.Agr.

38. WOOL TEXTILE RESEARCH LABORATORIES.

Senior Officer-in-charge—F. G. Lennox, D.Sc.

At Wool Textile Research Laboratory, Melbourne—

Biochemistry Unit, 343 *Royal-parade, Parkville, Victoria—*

Officer-in-charge—F. G. Lennox, D.Sc.
Laboratory Secretary—C. Garrow, B.Com.
Principal Research Officer—W. G. Crewther, M.Sc.
Principal Research Officer—M. A. Jermyn, M.Sc., Ph.D.
Principal Research Officer—H. Lindley, B.A., Ph.D.
Senior Research Officer—R. B. D. Fraser, B.Sc. (Hons.), Ph.D.
Senior Research Officer—J. M. Gillespie, M.Sc.
Senior Research Officer—S. J. Leach, B.Sc.Tech., Ph.D. (abroad).
Senior Research Officer—T. A. Pressley, B.Sc.
Senior Research Officer—W. E. Savige, M.Sc., Ph.D.
Senior Research Officer—D. H. Simmonds, M.Sc., Ph.D.
Senior Research Officer—J. M. Swan, B.Sc., Ph.D.
Senior Research Officer—E. O. P. Thompson, M.Sc., Ph.D., Dip.Ed.
Senior Research Officer—E. F. Woods, M.Sc.
Research Officer—B. S. Harrap, M.Sc., Ph.D.
Research Officer—J. P. E. Human, M.Sc., Ph.D.
Research Officer—J. A. Maclaren, M.Sc., Ph.D.
Research Officer—T. P. MacRae, M.Sc.
Research Officer—I. J. O'Donnell, M.Sc. (abroad).
Research Officer—G. E. Rogers, M.Sc. (abroad).
Research Officer—C. M. Roxburgh, B.Sc. (Hons.), Ph.D.
Research Officer—P. H. Springell, M.A., Ph.D.
Research Officer—G. Youatt, B.Sc. (Hons.), Ph.D.
Technical Officer—L. M. Dowling, B.Sc.
Technical Officer—A. B. Mcquade, B.Sc.
Technical Officer—I. Stapleton, Dip.Chem.
Technical Officer—K. I. Wood, A.R.M.T.C.

t Wool Textile Research Laboratory, Sydney—

Physics and Engineering Unit, The Hermitage, 338 *Blaxland-road, Ryde, New South Wales—*

Officer-in-charge—V. D. Burgmann, B.Sc., B.E.
Technical Secretary—H. W. M. Lunney, B.Sc., B.E.
Principal Research Officer—J. G. Downes, B.Sc. (Hons.).
Principal Research Officer—N. F. Roberts, M.Sc.
Senior Research Officer—M. Feughelman, B.Sc. (Hons.).
Senior Research Officer—H. W. Holdaway, B.Sc. (Hons.), B.E.
Research Officer—M. W. Andrews, B.Sc. (Hons.) (abroad).
Research Officer—K. Baird, M.Sc. (abroad).
Research Officer—E. G. Bendit, M.Sc.
Research Officer—J. F. P. James, M.Sc.
Research Officer—Miss V. Laws, M.Sc.
Research Officer—D. T. Liddy, B.Sc. (Hons.)
Research Officer—P. Nordon, B.Sc. (Hons.) (abroad).
Research Officer—I. M. Stuart, M.Sc.
Senior Technical Officer—A. R. Haly, B.Sc.
Senior Technical Officer—B. G. Leary, A.S.T.C.
Technical Officer—J. E. Algie, A.S.T.C.
Technical Officer—Miss J. C. Griffith, M.Sc.
Technical Officer—B. J. Rigby, A.S.T.C.
Technical Officer—G. L. Stott, A.S.T.C.
Technical Officer—A. G. Stutter, B.Sc. (Hons.).

At Wool Textile Research Laboratory, Geelong, Victoria—

Officer-in-charge—M. Lipson, B.Sc., Ph.D.
Technical Secretary—T. Topham, A.M.I.I.A., A.T.I.
Senior Research Officer—D. L. C. Jackson, B.Sc. (Hons.).
Senior Research Officer—G. W. Walls, B.Sc.
Senior Research Officer—G. F. Wood, B.Sc., Ph.D.
Research Officer—C. A. Anderson, B.Sc.
Research Officer—J. H. Bradbury, M.Sc., Ph.D.
Research Officer—J. Delmenico, B.Sc.
Research Officer—A. J. Farnsworth, M.Sc., Ph.D.
Research Officer—J. R. McPhee, B.Sc., Ph.D.
Research Officer—C. H. Nicholls, B.Sc., Ph.D.
Research Officer—D. S. Taylor, B.A., B.Sc., Ph.D.
Senior Technical Officer—A. R. W. Lee, B.Sc.
Senior Technical Officer—B. O. Lavery.
Technical Officer—G. C. West, A.G.Inst.Tech.
Technical Officer—M. A. Higgins, A.G.Inst.Tech.

XXXV. PUBLISHED PAPERS.

The following papers have been published during the year. Letters Patent granted to the Organization during the year are also included:—

1. Animal Genetics Section.

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[†††] Department of Morbid Anatomy, University College Medical School, London.

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4. DIVISION OF BUILDING RESEARCH.

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† Department of Agriculture and Stock, Queensland.

** Department of Organic Chemistry, University of Sydney.

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6. DAIRY RESEARCH SECTION.

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XXXVI. FINANCE.

1. Expenditure.

The statement of expenditure from 1st July, 1955, to 30th June, 1956, is as follows:—

	£	£	£
a) Salaries and contingencies			284,134*
b) Investigations—			
(i) Animal Health and Production Problems		629,971	
Less contributions from—			
Wool Research Trust Account	262,804		
Australian Dairy Produce Board	2,000		
Australian Meat Board	4,841		
Ian McMaster Bequest	4,542		
Alex. Fraser Memorial Fund	300		
Wm. McIlrath Fellowship	2,250		
Burdekin Bequest (Drought feeding)	1,600		
Special Revenue Funds—			
Burdekin Bequest	929		
"Gilruth Plains" Field Station	15,816		
"Belmont" Field Station	5,936		
		301,018	
			328,953
(ii) Biochemistry and General Nutrition Problems		113,101	
Less contributions from—			
Wool Research Trust Account	40,700		
Australian Wool Board	93		
		40,793	
			72,308
(iii) Plant Problems—Division of Plant Industry		664,284	
Less contributions from—			
Wool Research Trust Account	121,499		
Australian Meat Board	1,500		
Special Revenue Fund—Samford Farm	80		
		123,079	
			541,205
(iv) Entomology Problems			188,985
(v) Soils and Irrigation Problems of Irrigation Settlements—			
(*a*) Citricultural—Research Station, Griffith		46,078	
Less contributions from—			
N.S.W. Water Conservation and Irrigation Commission	2,000		
Special Revenue Fund—Griffith Research Station	3,081		
		5,081	
			40,997
(*b*) Viticultural—Research Station, Merbein		65,739	
Less contributions from—			
Dried Fruits Control Board	1,600		
Mildura Co-op. Fruit Company	250		
Irymple Packing Company	250		
Red Cliffs Co-op. Fruit Company	250		
Aurora Packing Company	250		
Co-op. Dried Fruits Sales Ltd.	250		
Nyah-Woorinen Enquiry Committee	140		
		2,990	
			62,749
			103,321
(vi) Soil Problems			202,816
(vii) Food Preservation and Transport Problems		220,753	
Less contributions from—			
N.S.W. Department of Agriculture	1,955		
Metropolitan Meat Industry Commission	500		
Queensland Meat Industry Board	1,275		
Australian Meat Board	500		
Australian Egg Board	750		
Commonwealth Can Makers' Association	415		
Department of Primary Industry	14,449		
Various Contributors	93		
Department of Scientific and Industrial Research (U.K.)	1,079		
		21,016	
			199,737
(viii) Forest Products Problems		291,871	
Less contributions from—			
Australian Paper Manufacturers Ltd.	1,410		
Associated Pulp and Paper Mills Ltd.	1,000		
Australian Newsprint Mills	1,000		
New Zealand Forest Products Ltd.	500		
Department of Territories	3,346		
General Donations	2,220		
Pole Strength Research Account	929		
		10,405	
			281,466
(ix) Mining and Metallurgy		36,916	
Less contributions from—			
Australasian Institute of Mining and Metallurgy	1,000		
State Electricity Commission	90		
General Donations	94		
		1,184	
			35,732

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* The main items of expenditure under this heading are salaries of the Administrative Staff at the Organization's Head Office; salaries and expenses of ficers at the Liaison Offices in London and Washington; staff and upkeep of State Committees; travelling expenses of Head Office Staff; and general office penditure.

	£	£	£
(x) Radio Research	..	37,870	
Less contribution from—			
Postmaster-General's Department	9,467		
		9,467	
			28,403
(xi) Research Services	..	225,758	
Less contribution from—			
Wool Research Trust Account	6,900		
		6,900	
			218,858
(xii) Industrial Chemistry	..	512,771	
Less contributions from—			
Cement and Concrete Association	1,500		
Mt. Morgan Ltd. and Mt. Lyell Mining and Railway Co. Ltd.	1,142		
Australian Atomic Energy Commission	6,400		
		9,042	
			503,729
xiii)) Fisheries Investigations	..	167,992	
Less contributions from—			
N.S.W. Government	250		
Department of the Navy	1,765		
		2,015	
			165,977
(xiv) Mathematical Statistics	..	..	56,896
(xv) National Standards Laboratory	..	497,914	
Less contribution from—			
Department of Defence Production	220		
		220	
			497,694
(xvi) Tribophysics	..	..	86,293
(xvii) Building Research	..	..	136,935
(xviii) Plant Fibre Research	..	..	38,294
(xix) Radiophysics Research	..	307,916	
Less contribution from—			
Snowy Mountains Hydro-electric Authority	4,650		
		4,650	
			303,266
(xx) Metallurgical Research	..	..	12,700
(xxi) Nuclear Energy Research	..	..	10,168
(xxii) Meteorological Physics	..	..	68,038
(xxiii) Dairy Research	..	58,405	
Less contribution from—			
Australian Dairy Produce Board	4,514		
		4,514	
			53,891
(xxiv) Wool Textile Research	..	334,095	
Less contributions from—			
Wool Research Trust Account	322,065		
Department of Supply	1,000		
Associated Woollen and Worsted Textile Manufacturers of Australia	2,227		
		325,292	
			8,803
(xxv) Fuel Research	..	137,113	
Less contribution from—			
Joint Coal Board	1,250		
		1,250	
			135,863
(xxvi) Wildlife Survey	..	97,750	
Less contributions from—			
Wool Research Trust Account	52,658		
George Aitken Pastoral Research Trust	71		
Northern Territory Administration	395		
		53,124	
			44,626
(xxvii) Land Research and Regional Survey	..	122,382	
Less contributions from—			
Department of National Development	20,179		
Department of Territories	15,817		
		35,996	
			86,386
(xxviii) Genetics	..	40,796	
Less contributions from—			
Wool Research Trust Account	20,030		
N.S.W. State Cancer Council	702		
Commonwealth Bank	34		
		20,766	
			20,030
(xxix) Miscellaneous—			
(*a*) Biophysical Research	..	1,179	
(*b*) Oenological Research	..	7,132	
(*c*) Extra-mural Investigations	..	13,262	
(*d*) Farm Mechanization Research	..	5,264	
(*e*) Various	..	4,404	
		31,241	
Less contributions from—			
Australian Wine Research Institute	3,566		
Science and Industry Endowment Fund	815		
Commonwealth Bank	3,500		
		7,881	
			23,360
(xxx) Unforeseen and Urgent	..	..	—
Total of Item (*b*)—Investigations	..	..	4,455,158

	£	£	£
(*c*) Grants—			
(i) Research Associations—			
Leather Research Association	7,107		
Bread Research Institute	7,500		
		14,607	
(ii) Overseas Research Studentships		42,259	
		56,866	
Less contributions from—			
Wool Research Trust Account	3,825		
Science and Industry Endowment Fund	1,486		
		5,311	
			51,555
Total Salaries and Contingencies, Investigations and Grants			4,790,847
Less receipts from sales of equipment, publications, &c., and revenue earned by Divisions and Sections, details of which are shown in Section 5			74,534
			4,716,313

2. CONTRIBUTIONS AND DONATIONS.

The following statement shows the receipts and disbursements during the year 1955-56 of the funds provided by outside bodies and recorded in the special account entitled "The Specific Research Fund" (formerly "The Specific Purposes Trust Account")—with the exception of the Wool Industry Fund, details of which appear in Section 4:—

	Receipts 1955-56 and balances brought forward from 1954-55.	Expenditure 1955-56.
	£	£
Commonwealth Bank (Animal Health and Production, Genetics, and Farm Mechanization Investigations)	3,809	3,534
Australian Wool Board (Biochemistry and General Nutrition Investigations—Sheep Research)	882	93
Australian Dairy Produce Board (Mastitis Investigations)	2,000	2,000
W. McIlrath Research Fellowship Fund (Expenses of Fellowship—Animal Husbandry)	2,250	2,250
Australian Meat Board (Cattle Breeding Investigations)	3,887	3,887A
Australian Meat Board (Caseous Lymphadenitis Investigations — Animal Health and Production)	399	399
Australian Meat Board (Bovine Pleuropneumonia Investigations)	90	90
Australian Meat Board (Parasitological Studies of Cattle)	431	..
Australian Dairy Produce Board (Parasitological Studies of Cattle)	216	..
Alexander Fraser Memorial Fund (Animal Health and Production Investigations)	300	300
N.S.W. State Cancer Council (Animal Health and Production—Cancer Research Project)	1,500	702
Estate of the late Captain Ian McMaster (Animal Health and Production Investigations)	4,637	4,591B
Australian Meat Board (Brigalow Investigations—Plant Industry)	1,500	1,500
West Australian Golf Association (Plant Industry Investigations)	51	..
United Graziers' Association of Queensland—Buffalo Fly and Cattle Tick Investigations (Entomology)	172	..
Australian Hide and Leather Industries Board (Entomology)	4,174	..
General Donations (Division of Entomology)	32	..
Burdekin Bequest (Drought Feeding Investigations)	1,600	1,600
N.S.W. Water Conservation and Irrigation Commission (Maintenance of Griffith Research Station)	2,000	2,000
Mildura Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Irymple Packing Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Red Cliffs Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Aurora Packing Company (Dried Vine Fruits Investigations, Merbein)	250	250
Co-op. Dried Fruit Sales Ltd. (Dried Vine Fruits Investigations, Merbein)	250	250
Dried Fruits Control Board (Dried Fruits Investigations)	1,600	1,600
Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations)	440	140
Australian Meat Board (Meat Investigations)	500	500
Metropolitan Meat Industry Board of New South Wales (Meat Investigations)	500	500
Queensland Meat Industry Board (Meat Investigations)	1,275	1,275
Department of Primary Industry (Mutton Dehydration Investigations)	9,110	8,765
N.S.W. Department of Agriculture (Food Investigations)	1,000	1,000
Department of Primary Industry (Fruit Fly Investigations—Food Investigations)	6,017	5,684
W. Angliss Ltd. (Division of Food Preservation and Transport)	51	..
Apple and Pear Board (Food Investigations)	500	..
L. Berger and Sons (Division of Food Preservation and Transport)	100	..
Various Contributors (Division of Food Preservation and Transport)	1,575	93
Australian Egg Board (Division of Food Preservation and Transport—Egg Investigations)	750	750
Commonwealth Can Makers' Association (Division of Food Preservation and Transport—Tinplate Investigations)	630	415
Department of Scientific and Industrial Research (U.K.)—Co-operative Meat Investigations (Food Preservation and Transport)	2,207	1,079
N.S.W. Department of Agriculture—Quick Freezing of Fruit and Vegetables (Division of Food Preservation and Transport)	1,119	1,014C
Australian Paper Manufacturers Ltd. (Paper Pulp Investigations)	1,409	1,409
Australian Newsprint Mills (Paper Pulp Investigations)	1,000	1,000
Associated Pulp and Paper Mills Ltd. (Paper Pulp Investigations)	1,000	1,000
New Zealand Forest Products Ltd. (Paper Pulp Investigations)	500	500
Sundry Contributors (Forest Products Investigations)	7,899	2,220
General Donations—Pole Strength Research (Forest Products)	8,582	929
Department of Territories (Development of Pulp and Paper Industry in New Guinea)	3,346	3,346

A.—Includes adjustment of 1954–55 expenditure.
B.—Includes £49 which relates to 1954–55.

C.—Includes adjustment of 1954–55 expenditure.

	Receipts 1955-56 and balances brought forward from 1954-55.	Expenditure 1955-56.
	£	£
Australasian Institute of Mining and Metallurgy (Mineragraphic Investigations)	1,000	1,000
Postmaster-General's Department (Radio Research)	9,899	9,466D
Drug Houses of Australia (Division of Fisheries—Agar Production)	25	. .
Miscellaneous Contributors (Division of Industrial Chemistry)	1,822	. .
Department of Supply (Textile Degradation Investigations)	1,000	1,000
Mt. Morgan Ltd. and Mt. Lyell Mining and Railway Co. Ltd. (Industrial Chemistry—Co-operative Investigations)	1,142	1,142
N.S.W. Government (Fisheries Investigations)	250	250
Consolidated Zinc Pty. Ltd.—Lead-copper Prospect, N.T. (Industrial Chemistry)	1,000	. .
State Electricity Commission of Victoria—(Mineragraphic Investigations—Geological Consultations)	1,000	90
Australian Atomic Energy Commission—(Industrial Chemistry—Extraction of Uranium from Leach Liquors)	6,400	6,400
Department of the Navy (Marine Fouling Investigations—Division of Fisheries)	2,081	1,765
Australian Cement Manufacturers (Cement Investigations — Industrial Chemistry)	1,500	1,500
Department of Defence Production—Examination of Gauges (Metrology)	750	220
General Donations (Division of Physics)	500	. .
Committee for Dried Fruit Marketing (Division of Meteorological Physics)	12	. .
Sundry Contributors (Commonwealth Scientific and Industrial Research Organization—Publications)	24	. .
Science and Industry Endowment Fund	2,301	2,301
Miscellaneous Contributors (Mathematical Instruments Section)	126	. .
Miscellaneous Contributors (Mineragraphic Investigations)	166	94
Wool Scourers, Carbonizers, and Fellmongers Federation of Australia (Wool Textile Research)	3,000	. .
General Donations (Division of Building Research)	1,030	. .
Shell (Chemical) Aust. Pty. Ltd.—Moth-proofing Investigations (Wool Textile Research)	500	. .
Patons and Baldwins Ltd.—Solvent Degreasing (Wool Textile Research)	1,250	. .
Department of National Development—Kimberley Research Station	1,376	1,230
Australian Dairy Produce Board (Dairy Research Laboratory—Cheese Investigations)	4,300	4,300
Australian Wine Research Institute (Oenological Research)	3,566	3,566
Snowy Mountains Hydro-electric Authority (Cloud Seeding Investigations—Division of Radiophysics)	12,500	4,650
Australian Dairy Produce Board (Cheese Making Project—Dairy Research)	214	214
Department of Territories (Resources Survey—Papua and New Guinea)	15,817	15,817
Department of National Development (Northern Australia Regional Survey)	19,655	18,950
Associated Woollen Worsted Textile Manufacturers of Australia (Wool Textile Research)	4,259	2,227
Various Contributors (International Wool Textile Research Conference)	50	. .
N.T. Administration—Goose Damage to Rice Crops (Wild Life Investigations)	395	395
Joint Coal Board (Coal Investigations)	1,250	1,250
George Aitken Pastoral Research Trust (Wildlife Survey Section)	94	71
Special Revenue Fund—"Belmont" Field Station, Rockhampton (Animal Health and Production Investigations)	6,277	6,277
Special Revenue Fund—National Field Station, "Gilruth Plains", Cunnamulla (Animal Health and Production Investigations)	17,576	17,576
Special Reserve Fund—National Field Station, "Gilruth Plains", Cunnamulla (Animal Health and Production Investigations)	15,000	5,208
Special Revenue Fund—Grazing Trials, Samford Farm (Plant Industry Investigations)	80	80
Special Revenue Fund—Burdekin Bequest (Animal Health and Production Investigations)	1,575	929
Special Revenue Fund — Research Station, Griffith (Citricultural Investigations)	17,574	6,331
Radio Astronomy Trust (Division of Radiophysics)	1,168	1,168
Suspense Account	Cr. 3,059E	. .
	238,735	172,882

D.—Includes adjustment of 1954–55 expenditure.

E.—Adjustment will be effected in the appropriate contributors' accounts during 1956–57.

3. WOOL RESEARCH TRUST ACCOUNT.

A credit balance of £279,037 was brought forward from 1954-55 in the Wool Research Trust Account. During 1955-56 the sum of £594,414 was credited to the account, comprising £409,207 received from the Department of Primary Industry, £50,238 representing proceeds of sale of produce, and £134,969 transferred from the Wool Industry Fund to meet the deficiency in the Wool Research Trust Account.

Complete details of transactions during 1955-56 are as follows:—

	£	£	£
Balance in Account, July 1, 1955			279,037
Receipts 1955-56.			
Department of Primary Industry		409,207	
Revenue—			
Animal Health and Production—			
Cobram Field Station	1,353		
Regional Pastoral Laboratory, Armidale	17,082		
Sheep Biology Laboratory, Prospect	2,962		
McMaster Field Station	710		
McMaster Laboratory	552		
Plant Industry—			
"Glen Lossie" Field Station, Kojonup	9,434		
Falkiner Memorial Field Station, Deniliquin	9,687		
Mitchell Laboratory, Trangie	53		
Biochemistry and General Nutrition—"Glenthorne" Field Station	4,834		
Wool Textile Research Laboratories—			
Textile Laboratory, Geelong	2,265		
Biochemistry Laboratory, Melbourne	538		
Textile Laboratory, Sydney	236		
Wild Life—Wild Life Investigations	532		
		50,238	
Amount transferred from Wool Industry Fund		134,969	
Total Receipts 1955-56			594,414
			873,451

Expenditure 1955-56.

	£	£	£
Division of Animal Health and Production—			
Parkville—			
Sheep Physiology Investigations—Tooradin	5,340		
Fodder Production—Cobram ..	3,937		
		9,277	
McMaster Laboratory—			
Parasitology Investigations—New South Wales	12,320		
Parasitology Investigations — Western Australia	500		
Dipping and External Parasites ..	1,672		
Biochemical Investigations ..	5,073		
Hollerith Equipment	2,710		
Biological Investigations ..	300		
		22,575	
Yeerongpilly—			
Sheep Blowfly Investigations ..	3,940		
		3,940	
Sheep Biology Laboratory, Prospect—			
Administrative and General Expenses	73,244		
Fleece Analysis	10,085		
Wool Biology	62,320		
Strain Trial	7,829		
		153,478	
Armidale	..	60,557	
National Field Station, "Gilruth Plains"—			
Animal Breeding and Strain Trial Investigations	..	5,251	
McMaster Field Station—			
Wool Production and Sheep Breeding	..	4,649	
Frodsley, Tasmania—			
Sheep Investigations	..	3,077	
			262,804
Division of Plant Industry—			
Agrostology Investigations ..	..	121,499	
Research Services—			
Agricultural Research and Extension Liaison	6,061		
Wool Publications	839		
		6,900	
Division of Industrial Chemistry—			
Expenditure on Wool Textile Research—			
Chemical Physics Investigations ..	11,442		
Organic Chemistry Investigations	15,727		
Physical Chemistry Investigations	2,946		
		30,115	
Division of Biochemistry and General Nutrition—			
Biochemical and Nutritional Investigations	..	40,700	
Wool Textile Research Laboratories—			
Wool Textile Research	..	291,951	
Wildlife Survey Section—			
Wildlife Survey	..	52,658	
Animal Genetics Section—			
Animal Genetics Investigations ..	..	20,030	
Miscellaneous—			
Overseas Studentships	..	3,825	
Total C.S.I.R.O. Investigations	..	..	830,482
Grants from Wool Research Trust Account to institutions undertaking research in agricultural economics relating to wool production—			
Department of Primary Industry—			
Bureau of Agricultural Economics	37,236		
Wool Adviser	5,733		
Total Department of Primary Industry Expenditure ..	..	42,969	
Total Expenditure 1955-56 ..	..	..	873,451
Balance carried forward to 1956-57 ..	..	..	Nil

4. WOOL INDUSTRY FUND.

A credit balance of £48,645 was brought forward from 1954-55 in the Wool Industry Fund Account. A further £429,010 was received during 1955-56. Of this amount £134,969 was transferred to the Wool Research Trust Account to meet the deficiency in that account (see para. 3). Expenditure during 1955-56 amounting to £317,885 was incurred as follows:—

Expenditure by C.S.I.R.O. Divisions and Sections.	£	£	£	£
Biological Research—				
Animal Health and Production—				
Sheep Biology Laboratory, Prospect—				
Equipment for Climate Rooms	18,389			
Equipment	11,048			
Development expenditure —fencing, roads, water supply, &c.	1,849			
		31,286		
Regional Pastoral Laboratory and "Chiswick" Field Station, Armidale — Construction of small buildings and roads and provision of services	3,543			
		3,543		
Cobram Field Station—				
Equipment	922			
		922		
McMaster Laboratory—Developmental expenditure on Parasitology block at McMaster Field Station ..	3,733			
		3,733		
			39,484	
Biochemistry and General Nutrition—				
Glenthorne Experimental Station—				
Experimental sheep units ..	..	1,654		
Fences, water reticulation, &c.	..	639		
			2,293	
Plant Industry—				
Falkiner Memorial Field Station, Deniliquin—				
Developmental expenditure—fencing, hayshed, irrigation, &c.	..	1,142		
"Glen Lossie" Field Station, Kojonup, Western Australia—				
Developmental expenditure—clearing, fencing, water supply, &c.	..	4,040		
Canberra Laboratory—				
Glass-house and fertilizer room	..	2,350		
Dickson Experimental Station, Canberra—				
Fencing, feed racks and silos	..	1,261		
Mitchell Laboratory, Trangie—				
Improvements	..	45		
			8,838	
Wildlife Survey—				
Myxomatosis and Rabbit Investigations, Albury—				
Fencing	..	846		
			846	
Wool Texile Research—				
Biochemistry Laboratory, Melbourne—				
Plant	1,300			
Equipment	1,631			
		2,931		
Textile Laboratory, Geelong—				
Buildings and site ..	6,766			
Textile machinery ..	7,164			
Plant	17,561			
		31,491		
Physics and Engineering Unit, Sydney—				
Plant	9,447			
Textile Machinery ..	309			
Modifications to laboratory	7,123			
		16,879		
			51,301	
				102,762

Expenditure by Department of Works on C.S.I.R.O. Buildings.	£	£	£	£
Biological Research—				
Animal Health and Production—				
Sheep Biology Laboratory, Prospect—				
Animal House No. 1 . .	16,355			
Air conditioning prefabricated building . .	7,245			
Main Laboratory . .	13,764			
Climate controlled building	253			
Cottage No. 2	180			
Amenities building . .	2,819			
Acquisition of land . .	Cr. 16			
Construction of roadway . .	2,657			
Manure pit	10			
		43,267		
			43,267	
Plant Industry—				
Head-quarters, Agrostology Section, Canberra—				
Agrostology and Pasture Chemistry prefabrications . .		5,708		
Western Australian Investigations—				
Regional Laboratory, Perth	233			
Staff Cottage, Kojonup . .	882			
		1,115		
Regional Pastoral Laboratory and Falkiner Memorial Field Station, Deniliquin—				
Staff cottage	54			
Three cottages	3,422			
Acquisition of site . .	469			
		3,945		
			10,768	
Biochemistry and General Nutrition—				
Glenthorne Experimental Station—				
Hay and chaff shed . .	3,121			
		3,121		
			3,121	
Animal Genetics—				
Extensions to Zoology Building, University of Sydney . .	14,819			
		14,819		
			14,819	
Minor Works—				
New South Wales	2,690			
Victoria	666			
Western Australia	314			
Australian Capital Territory . .	21			
		3,691		
			3,691	
Wool Textile Research—				
Wool Textile Research Laboratories—				
Biochemistry Laboratory Melbourne—				
Laboratory building . .	10,206			
		10,206		
Textile Laboratory, Geelong—				
Building for electricity sub-station	3,768			
Development of site . .	1,228			
Fire alarm system . .	400			
		5,396		
Textile Laboratory, Sydney—				
Laboratory building . .	45,526			
Workshop—store building	2,757			
		48,283		
			63,885	
Minor Works—				
New South Wales	1,010			
Victoria	1,824			
		2,834		
			2,834	
				142,385

Grants from Wool Industry Fund for Extra-mural Co-operative Wool Research.	£	£	£	£
Biological Projects—				
Victoria—				
Melbourne University—				
Electrolyte physiology studies	6,000			
Department of Lands and Survey—				
Rabbit Investigations . .	5,785			
		11,785		
Western Australia—				
Institute of Agriculture—				
Ruminal flora studies . .	4,750			
Department of Agriculture—				
Clover infertility . .	1,800			
		6,550		
South Australia—				
Roseworthy Agricultural College—				
Progeny testing	3,995			
Waite Institute—				
Agronomy and entomology	5,350			
University of Adelaide—				
Animal ecology	600			
		9,945		
Australian Capital Territory—				
Australian National University—				
Myxomatosis investigations	1,500			
		1,500		
Queensland—				
Department of Agriculture and Stock—				
Fertility and neo-natal mortality	1,100			
Progeny testing and wool metrology	300			
Ovine brucellosis . .	400			
Alterations at Toorak Field Station	5,570			
University of Queensland—				
Sheep physiology . .	1,850			
Acclimatization studies . .	485			
		9,705		
New South Wales—				
University of Technology—				
Wool clip analysis . .	5,759			
University of Sydney—				
Animal physiology investigations	2,500			
Department of Agriculture—				
Disordered metabolism . .	2,246			
Ectoparasites	3,500			
Erection of sheep house, Trangie	5,500			
Fleece testing, Trangie . .	1,000			
		20,505		
			59,990	
Wool Textile Research—				
Gordon Institute of Technology—				
Wool Textile investigations . .	3,919			
Wool Industry Research Association, U.K.	1,254			
		5,173		
			5,173	
				65,163
Additional Items Sponsored by C.S.I.R.O.—				
Expenses in connexion with Wool Textile Conference, 1955	7,575			
		7,575		
			7,575	
				7,575
				317,885

5. MISCELLANEOUS RECEIPTS.

During 1955-56 miscellaneous receipts amounted to £74,534. Of this amount £17,122 represented proceeds of sales of equipment, publications, &c. The balance of £57,412 represented revenue earned by Divisions and Sections apart from the Special and Wool Revenue included under Sections 2 and 3 respectively. Details of the receipts are as follows:—

Revenue Receipts.

	£	£
Division of Animal Health and Production—		
Sale of Contagious Pleuropneumonia Vaccine	9,130	
Mastitis Investigations	3,604	
Parkville Laboratory	214	
Toxaemic Jaundice Investigations, Parkville, Victoria	137	
Oestrus Experiments	1,900	
Poultry Breeding Investigations	10,612	
Contagious Pleuropneumonia Investigations	1,818	
Bacteriological Investigations	121	
Parasitological Investigations	625	
McMaster Field Station Revenue	1,840	
Veterinary Parasitology Laboratory	951	
Division of Plant Industry—		
Plant Industry Investigations, Canberra	4,348	
Stanthorpe Field Station	126	
Division of Entomology—		
Entomological Investigations	2	
Division of Soils—		
Merbein Research Station	4,746	
Soils Investigations	283	
Division of Food Preservation and Transport	777	
Division of Forest Products	376	
Ore-dressing Investigations	215	
Research Services—Film Unit	165	
Division of Industrial Chemistry—		
Industrial Chemistry Investigations	3,250	
Microanalysis Investigations	2,790	
Division of Fisheries	300	
Division of Metrology	6,578	
Division of Electrotechnology	810	
Division of Physics	1,225	
Division of Building Research	61	
Division of Radiophysics	155	
Meteorological Physics Section	4	
Wild Life Survey Section	37	
Land Research and Regional Survey, Katherine	45	
Fuel Research Section	167	57,412
Other Receipts—		
Sales of publications	2,788	
Sales of equipment, &c.	14,334	17,122
		74,534

The above sum was paid to the credit of the Trust Fund Science and Industry Account during 1955-56 and consequently reduced the requirements from Treasury sources by that amount (*see* Section 1).

6. WORKS PROJECTS (UNDER CONTROL OF C.S.I.R.O.).

Expenditure on works projects financed from Treasury funds made available directly to C.S.I.R.O. was as follows:—

	£	£	£
Plant Industry—			
Samford Experimental Station—			
Developmental expenditure	1,250		
Beerwah Field Station—			
Developmental expenditure	999		
Rodd's Bay Experimental Area—			
Fencing	28	2,277	
Meteorological Physics—			
Aspendale Laboratory—			
Multiple lysometer	327	327	
Food Preservation—			
Laboratory, Homebush—			
Alterations and additions to Metropolitan Meat Industry Board buildings	142		
University of Sydney—			
Grant for additional accommodation at Botany School	5,000		
Laboratory, Hobart—			
Plant	398	5,540	
Physics—			
Laboratory, Sydney—			
Hut and housing for solar telescope	1,426	1,426	
Radiophysics—			
Construction of Radio Telescope	1,168	1,168	10,738

7. MISCELLANEOUS SERVICES.

	£
Contribution to Commonwealth Agricultural Bureaux	38,329
Grant to Standards Association of Australia	45,000
Contribution to Chair of Aeronautics at University of Sydney (establishment and maintenance)	5,000
Grant to National Association of Testing Authorities	11,102
Australian and New Zealand Association for the Advancement of Science	1,000
	100,431

XXXVII. ACKNOWLEDGMENTS.

In various sections of this Report reference has been made as in previous years to the valuable assistance afforded by many State Departments, Universities, and other organizations and individuals. The Organization desires to express its gratitude for the help given by these bodies and persons in providing laboratory accommodation and other facilities and in many other ways. The Organization also wishes to acknowledge the assistance it has received from its Committees, the members of which have placed their knowledge and experience so freely at its disposal.

I. CLUNIES ROSS, Chairman
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S. H. BASTOW Executive.
H. J. GOODES
A. W. COLES

30th October, 1956.

Printed and Published for the GOVERNMENT of the COMMONWEALTH OF AUSTRALIA by
A. J. ARTHUR, Commonwealth Government Printer, Canberra.